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Predicting Invasion Risk of Non-Native Plants Using a Modified I-Rank Assessment

Justin B. Williams

University of Nebraska-Lincoln, jwillibird@yahoo.com

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**PREDICTING INVASION RISK OF NON-NATIVE PLANTS
USING A MODIFIED I-RANK ASSESSMENT**

by

Justin B. Williams

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PREDICTING INVASION RISK OF NON-NATIVE PLANTS
USING A MODIFIED I-RANK ASSESSMENT

Justin B. Williams, M.S.

University of Nebraska, 2013

Adviser: Craig R. Allen

Biological invasions are a global problem responsible for native species declines worldwide. Understanding the invasion risk from non-native species is important in establishing management goals and making decisions for managing native ecosystems. Useful modeling methods for quantifying or predicting invasion risk should consider research needs, data availability, and operate at an appropriate scale. I evaluated risk assessment methods towards answering a specific research question; which plant species pose the greatest risk of becoming invasive or having the greatest negative impact in Nebraska? I selected the I-Rank assessment method, which consists of 20 questions grouped into four risk categories or Subranks: impact on native species/ecosystems, current distribution/abundance, trend in distribution/abundance, and management difficulty. I used information from herbaria collections, agency reports, literature review, online databases, and expert opinion surveys to evaluate 56 non-native plant species. I modified the I-Rank method to operate at the state-level scale by adapting I-Rank questions for Nebraska. I also compared results from this state-level I-Rank assessment to results from an analysis conducted at the national scale. A distinct feature of the I-Rank assessment is that a range of possible answers is acceptable for each question. This feature allows for the incorporation of uncertainty and reduces the amount of inherent

subjectivity, but also presents a challenge in accounting for uncertainty. I present new methods for quantifying and visualizing sources of uncertainty in the I-Rank scores and provide conceptual risk assessment and management contexts for these methods. Results indicate that the predicted invasion risk often depends on the scale at which the I-Rank questions are evaluated. Ten of the species evaluated are noxious in neighboring states, but not likely to become invasive in Nebraska. The study identified numerous species likely to be invasive in Nebraska, including seven plants not recognized as noxious weeds or “watch list” species in Nebraska. I-Rank results for many species indicated high levels of uncertainty and require additional interpretation or research to make conclusions. I make suggestions for interpreting I-Rank results using available information to prioritize species for management decisions in Nebraska. I discuss relative strengths/weaknesses of the I-Rank method, offer conclusions/recommendations based on my results for Nebraska, and identify opportunities for future research. A similar approach could be used to adapt this method for other states or geographic areas of interest. I conclude that the I-Rank assessment provides a straightforward method for synthesizing information from numerous sources to evaluate invasive species threats at an appropriate scale to meet research needs and inform management decisions.

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1. INTRODUCTION

Biological invasions are a global problem responsible for native species declines worldwide (Vitousek 1994, Schmitz and Simberloff 1997). Invasion by non-native species can alter community composition (Rahel 2000), ecosystem processes (Flecker and Townsend 1994) and cause negative economic impacts (Vitousek et al. 1996). Understanding the ecology of invasive species is important in determining management goals for native species, such as prevention, mitigation, and protection. Determining environments that are susceptible to invasions can also provide information to prevent or manage invasive species threats. Invasion success may be determined by the interaction between characteristics of donor populations and the environments where species are introduced (Williams and Meffe 1998). Concepts in invasion/community ecology have provided theoretical insight into factors governing invasion success (Shea and Chesson 2002). Various modeling approaches have determined useful biological predictors of invasiveness. For example, positive correlates of plant invasion success include short juvenile period, short intervals between large seed crops, small seed mass, vegetative reproduction, and history of invasiveness (Rejmanek and Richardson 1996; Kolar and Lodge 2001). However, models based on ecological theory and biological predictors alone are not adequate for most predictive applications. This lack of predictability has led ecologists to develop context-specific models for predicting and/or explaining biological invasions.

Selecting the appropriate model to predict invasions should involve several considerations based on research needs. The ecological processes driving invasion patterns vary across spatial scales (Pauchard and Shea 2006). Therefore, models should be

developed at an appropriate scale to provide understanding for the particular situation. Selecting the best method may depend on the current stage of invasion, since there are often separate controls for each stage (Lodge 1993; Marchetti et al. 2004). Different stages have specific questions/goals associated with them, for example prevention, eradication, or restoration. Innovations in population biology-based invasion models could be useful for prevention/management of invasive species (Sakai et al. 2001). However, Simberloff (2003) points out that the science required for a decision on a fast course of action is often minimal, and that waiting to do more can make control difficult or impossible. Empirical approaches have included spatial pattern studies correlating the abundance of invaders and community diversity, invader addition studies, assembly studies examining community diversity and invasion through time, and direct experimental manipulation of diversity in constructed communities (Levine and D'Antonio 1999). Selecting the most useful type of model is largely dependent on the given situation and research needs.

Although invasive species occur across all taxonomic groups, I focused my research on plants. Invasive plants are a serious ecological problem and worldwide economic impacts related to weeds are estimated to be over \$87 billion per year (Lambdon and Hulme 2006). Ranges of plant species are increasingly expanding by invasion of new areas worldwide, which is largely due to worldwide trends in the horticulture, agriculture, and shipping industries (McNeely 1999; Perrings et al. 2005). Nebraska and the Great Plains region face similar threats from invasive plant species (Stubbendieck et al. 2003).

Nebraska has several measures in place to prevent/minimize invasive plant impacts. The Nebraska Noxious Weed List (Noxious List) contains taxa designated as “a serious threat to the economic, social, or aesthetic well-being of the residents of the state,” (Table 1; Nebraska Department of Agriculture [NDA] 2008). The Nebraska Invasive Species Watch List (NIS Watch List), consists of “potentially harmful invasive plants that need monitoring,” (Table 2; Nebraska Weed Control Association [NWCA] 2008a). Nebraska also has a statewide monitoring and control program administered through the Nebraska Weed Control Association (NWCA) and the Nebraska Department of Agriculture (NDA) Noxious Weeds Program and is comprised of weed authorities in all 93 Nebraska counties. Groups of counties are organized into Weed Management Areas (WMAs) that bring together landowners and managers (private, city, county, state, and federal) in geographical areas to coordinate efforts and expertise for invasive weeds (Figure 1). Numerous stakeholder agencies have research needs related to invasive species in Nebraska (Nebraska Invasive Species Project [NISP] 2008).

In collaboration with the NISP (2008), I met and discussed research needs with numerous individuals from stakeholder agencies who have interest and/or expertise in invasive plants in Nebraska. Through these informal discussions, I was able to ascertain three specific needs for invasive species research in Nebraska: (1) continued/improved monitoring of statewide trends in distribution/abundance of invasive species; (2) a “user-friendly” synthesis of information that could be made accessible to various stakeholders for incorporation into management decisions; (3) information to help determine which species pose the greatest risk of becoming invasive or having the greatest negative impact in Nebraska. Several questions are relevant to these research needs and guided my

research. For example, which non-native plant species listed as invasive in surrounding states are likely to become invasive in Nebraska? Of the approximately 500 non-native plants in Nebraska (Rolfmeier and Steinauer 2006), which species could become invasive? Another need related to the NIS Watch List is that, although there are certain criteria for listing of species on the list (Appendix A), there is not a defined methodology or framework for evaluating potential species by the Watch List Committee (personal communication Mitch Coffin-Nebraska Department of Agriculture; Chris Helzer-The Nature Conservancy). Elevation of a species to “Watch List Status” is a significant management decision because it provides for focused statewide monitoring for those species through the NWCA and partners, including training for plant identification and control methods. Because of the extra degree of scrutiny and reporting requiring, NWCA has expressed the desire to keep the number of species listed on the NIS Watch List to a manageable number. Therefore, the decisions about which species to list are important since there are a limited number of slots available on the list and administration of the Noxious and NIS Watch lists guides the statewide monitoring and reporting program. My research goals are (1) to develop and evaluate a risk assessment method to assess plant species for invasion ability in Nebraska; (2) synthesize information about potential invasive plants in Nebraska in an accessible format and effectively communicate results; and (3) recommend plants for consideration and possible listing on the NIS Watch List. By researching these three goals, I hope to contribute towards the ongoing improvement of monitoring, management decisions, and communication about the potential impact of invasive species in Nebraska.

Most non-native species are not successful in becoming established or invasive. Williamson (1996) proposed the “tens rule,” which states that about 10% of introduced species become established, and 10% of those introduced species become invasive, meaning only 1% of introduced species become invasive. Williamson provides numerous examples that closely approximate the 10% theory, as well as numerous exceptions. For the purpose of illustration, let us make the broad assumption that this theory holds true for Nebraska plants outside of other considerations. There are approximately 500 non-native plants documented in Nebraska (Rolfmeier and Steinauer 2006). Assuming that these 500 species are now established, there would have been approximately 5,000 species introduced. Therefore, Williamson’s theory would predict that 50 plant species would become invasive. Given the damaging effects of invasive species, a system for assessing and predicting species’ relative invasion risk would be helpful to prioritize research/monitoring, with the goal of determining which 50 species are most likely to be invasive in Nebraska. Determining which species are not likely to become invasive would also be valuable information because more attention could be focused on species with moderate, high, or unknown invasion risk. There are numerous established methods for assessing risk from non-native species. Selecting a method for a predictive model is largely dependent on the situation, research needs, and the amount of research time and effort needed to perform the assessment. These research tools can be combined or incorporated into more comprehensive risk assessment frameworks and/or adaptive management strategies.

Predictive invasive species risk models are generally concerned with answering two fundamental questions: (1) Where in the target region is the species likely to be

established? (2) What is the potential for economic or ecological impact? I have grouped my literature review into two modeling categories which basically correspond to the fundamental questions above: (1) Ecological Niche Modeling, and (2) Risk Assessments. Although there is often overlap between the two approaches, they provide a logical break in categorizing predictive modeling methods for invasive species.

A. Ecological Niche Models.

To determine where in a target region a species is likely to occur, Ecological Niche Models (ENM) typically generate a predicted range based on a set of independent environmental predictor variables, such as climate, topography, soil, and vegetation data. ENM, sometimes referred to as habitat suitability models, typically operate on landscape-scale environmental variables, exclude biological and smaller-scale data in niche considerations, and assume that a species niche is stable across recent timescales (Peterson et al. 1999). The technique of ENM allows assessment of the geographic areas at risk for invasion by a non-native species before introduction (Peterson and Vieglais 2001; Vander Zanden et al. 2004). ENM predict the fundamental niche, a set of abiotic parameters that identify suitable environment for a species (Grinnell 1917; Hutchinson 1957). ENM are typically calibrated with location data (and associated environmental data) from a species' native range. These location data represent the geographic extent of the realized niche, which, due to historical and biotic effects, is a subset of areas defined by the fundamental niche. One potential problem with ENM is that data summarizing the realized niche are often used to predict the fundamental niche in areas where the species isn't native, which could lead to under prediction. One solution is to supplement model calibration with data from an introduced range. A case study for predicting potential range

of a weed in Australia yielded appreciably different predictions for three model sets developed with data from the native range (Brazil), introduced range (South Africa), and combined locations (Kriticos et al. 2001).

Various niche matching applications for invasive species have employed numerous modeling methods including logistic regression, generalized linear models, generalized additive model, climate envelope, classification and regression trees, neural networks, and genetic algorithms (DeVaney et al. 2009; Jeschke and Strayer 2008; Loo et al. 2007; Meyer et al. 2008; Schussman et al. 2006; Thuiller et al. 2005; Beerling et al. 1995; Broennimann et al. 2007; Fitzpatrick et al. 2007; Reichard and Hamilton 1997). The processes generally involved in generating ENMs include: gathering relevant occurrence data and assessing its accuracy and comprehensiveness, gathering/vetting relevant predictor variable data, selecting an appropriate model based on the application and data availability, calibrating model based on location data (typically from the native range), evaluating the model using predictive performance on test data (typically from non-native range), mapping predictions to geographic space, and interpreting results (Elith and Leathwick 2009).

B. Risk Assessment Models

Risk assessment is a method for quantifying the likelihood of an event and determining the associated consequences or impact. In this way, one can prioritize and evaluate the need for precautionary or management actions. However, the term “risk assessment” can have several meanings. In a strictly technical sense, risk assessment refers to a qualitative or quantitative evaluation of the environmental and/or health risk

resulting from exposure to a chemical or physical agent (Landis 2004). However, in a general sense, it could be understood as any decision making process based on information about the likelihood and effects of some adverse event. Traditional risk assessments have been used to estimate the type and magnitude of risk to human health posed by exposure to chemical substances (Landis 2004), and have five components: a stressor, exposure, receptor, effect, and a response (Figure 2). This conceptual model can be applied to a number of scenarios, problems, or questions. For example, consider the question “Should I bring an umbrella to work today?” In this example, the stressor is the rain, the exposure is the chance of rain from the weather report, the receptor is the person, the effect is that the person will get wet (the severity of wetness could be quantified), and the response is that the person has an increased probability of catching a cold. In other words, risk assessment is the framework used to document the risk of a particular event or circumstance, estimating impacts, and evaluating system responses from incurring impacts.

The Environmental Protection Agency (EPA) describes risk assessment as “an evaluation of the probability of adverse ecological consequences resulting from one or more stressors” (EPA 1998). Although, risk assessments were developed to evaluate the risks of stressors to human health or wildlife, researchers have recently expanded the application of risk assessment to the study of non-native species (Bartell and Nair 2004; Anderson et al. 2004a; 2004b). Landis (2004) has developed a conceptual framework to assess ecological risk of potentially invasive species, and several researchers have applied this framework in different ecological systems. The conclusions from these types of biological risk assessments provide information to stakeholders, land managers, and

policy makers, and help them to develop strategies protecting natural resources.

Expanding the field of risk assessment into new disciplines requires adapting methods and terminology specific to the situation. For example, Landis (2004) describes four biological features that distinguish invasive species risk assessments from traditional risk assessments. First, the exposure to the stressor becomes the probability of a successful invasion. There are numerous factors that influence the success of an introduction, such as migration rate, habitat requirements, and biotic and abiotic characteristics of in the receiving environment. Second, the population size of the invader may increase and fluctuate once established. Third, there is a broad range of mechanisms by which the stressor can impact the receiving environment, such as direct and indirect competition, physical habitat alteration, and changes in biotic interactions. Fourth, “the processes that govern impacts are fundamentally ecological and evolutionary. These processes are therefore contingent, probabilistic, and dynamic” (Landis 2004). Consequently, in any invasive species risk assessment there is inherent uncertainty, which should be quantified and described in detail. Figure 3 shows the concept of risk assessment applied to invasive species assessments.

Several researchers have designed weed risk assessments to inform their decisions about possible importation of non-native species. In the United States, the Animal and Plant Health Inspection Service (APHIS) issued a summary of the guidelines for establishing a weed’s invasion potential (Lehtonen 2001). The APHIS guidelines include a structured evaluation template that consists of habitat suitability, agricultural and environmental damage potential, dispersal potential, and entry potential. A system implemented in Australia integrated forty-nine questions about history of invasiveness,

native climate, habitat preferences, and biological attributes into a scoring system to rank the potential invasiveness of weeds (Pheloung et al. 1999). A minimum of ten questions were answered to score the plants on the “weediness” scale from “benign” to “maximum weediness.” Based on the score, species could be accepted into the country, require further evaluation, or denied import. This system was also adapted to assess possible weeds in New Zealand (Williams et al. 2002) and Hawaii (Daehler et al. 2004).

Another approach is to investigate the invasion potential of previously established species to provide information for management priorities for specific areas or communities at risk. Hiebert and Stubbendieck (1993) ranked species based on a series of questions in different categories, including the significance of impact, ability to become a pest, and feasibility of control or management. They prioritized species for management considerations by graphing their results on axes of invasion threat versus difficulty of control, with highest management priority given to species with high threat and low/moderate control difficulty. Low priority was given to species that cause little impact, are virtually impossible to control, or both. This system was designed as a relatively small-scale analysis for specific parks or preserves and can be adapted for use at different locations.

On a larger scale, Randall (1996) developed a weed risk assessment method to rate over 100 established plants throughout California based on 20 questions about impact on native habitat, biological characteristics, distribution, abundance, and management potential. Plants were ranked high, medium, low, or insignificant for each question to determine the overall ranking. NatureServe subsequently published a similar weed assessment system called the Invasive Species Impact Rank, or I-Rank framework, which

was designed for use over larger and more diverse regions (Morse et al. 2004; Randall et al. 2008). Each potential weed is assessed based on its ecological impact, current and trend in distribution/abundance, and management difficulty. A distinct advantage of this assessment system is that a range of threat levels or “unknown” can be selected for each question if an absolute answer cannot be determined. This feature allows for the incorporation of uncertainty and reduces the amount of inherent subjectivity. The assigned score ranges from the four question subsets are then weighted and combined to determine the plant’s overall invasiveness rank or I-Rank. The I-Rank can be a single class (e.g. LOW) or a range of classes (e.g. LOW-MED), depending on the amount of uncertainty for each species. NatureServe has performed the I-Rank assessment for 500 plant species using the study area of the contiguous United States and published the results on their online Explorer Database (Natureserve 2008).

Evaluation of weed risk assessment systems is largely dependent on the specific needs of the intended audience. No system is accurate and/or useful in all situations (Stohlgren and Schnase 2006), but they can often be adapted to meet specific needs. Systems designed to exclude potentially invasive species from being imported would need to have a strict and defensible framework. The most useful assessments for management applications will provide information about native communities and/or geographic areas at risk, feasibility of control, and prioritize threats from potentially invasive species. Statistically testing the accuracy of an assessment system is difficult because many of the species are not present or were recently established with limited occurrence data. Therefore, many weed risk assessment predictions have not been evaluated for accuracy. However, the Pheloung et al. (1999) risk assessment method was evaluated and correctly

predicted 84% of invasive species in Australia (Daehler and Carino 2000), 93% in New Zealand (Williams et al. 2005), and 95% in Hawaii (Daehler et al. 2004). The success rates were ascertained by comparing the assessment's predictions with surveyed expert opinion and observed invasions of the assessed plants in the corresponding country or state. Like the risk assessments themselves, these evaluations involve some subjectivity. However, the evaluations do provide an indication of the usefulness of weed risk assessments as valuable tools to be used in conjunction with other quantitative, predictive, and directly testable models.

C. Combined/Novel Approaches

Lastly, while ENM and risk assessment methods for predicting invasive species have been presented as separate topics above, there is often overlap between the applications and a combination of approaches may be useful. For example, Allen et al. (2006) used a spatial risk assessment to characterize the risk of invasive fire ants with respect to two native bird species in South Carolina. Miller et al. (2010) used a novel spatial approach to assess potential impacts of invasive plant species and quantify risks for rare plants in Nebraska. These approaches illustrate one distinct advantage inherent in invasive species risk assessments, they are flexible methodological frameworks, which can be adapted to meet the needs of specific management applications.

2. METHODS

There are several attributes that are desirable in a method to assess risk for invasive species. Table 3 lists attributes that were instrumental in guiding my model

selection process. I evaluated each potential method against these criteria using an informal rating process. Hiebert and Stubbendieck (1993) point out several reasons for utilizing a structured decision analysis process when making management decisions. One example of a management decision which could utilize such an approach would be deciding species to be listed on the NIS Watch List. Summarizing and paraphrasing from Hiebert and Stubbendieck (1993), distinct advantages of an analytic decision approach are:

- Exchange of information encourages biologist/stakeholder involvement in the decision making process
- Adds validity to decisions, prevents compromising scientific principles by making decisions based on incomplete information,
- The process often demonstrates that inaction can have serious consequences,
- Prevents decisions being based on opinions and precedents, which may suffer from personal biases and political whims,
- Ensures that ecological knowledge is applied to the decision process,
- An analytical framework encourages researchers to consider the full range of factors and consequences of decisions,
- By documenting the procedures and decision rationale, the decisions have solid justification and are defensible.

Many of the advantages listed above are similar to opinions reported by stakeholders during my investigation of research needs. Because these ideas are insightful and central to my research objectives, I adopted them to drive my final selection of risk assessment method, which would ideally lend itself to this type of analysis for NIS Watch List decisions. Based on the considerations described above, I selected the I-Rank Assessment to rate the risk of potentially invasive plant species in Nebraska (Morse et al. 2004; Randall et al. 2008). This risk assessment can be adapted to the State of Nebraska and allows for the incorporation of uncertainty in evaluating invasion potential. Other risk assessment methods discussed in Section 1 were given consideration, but were eliminated due to requiring subjective decisions (leading to non-repeatable results), being too rigid to

adapt for Nebraska, and/or not being feasible for a large pool of candidate species due to difficulties in determining risk factors or compiling sufficient information. Lastly, the I-Rank method was judged to be an excellent candidate to leverage available information regarding non-native plants in Nebraska towards meeting research needs.

After selecting the risk assessment method to adapt for Nebraska, the next step was to determine which plant species to evaluate. Because there are approximately 500 non-native plant species known to occur in Nebraska (Rolfsmeier and Steinauer 2006), I used the following criteria to reduce the number of species to a more practical risk assessment candidate list. First, I selected all species listed on the Nebraska Noxious and NIS Watch Lists (Tables 1 and 2). Next, I selected all species listed as noxious weeds in the six states bordering Nebraska (Colorado, Wyoming, South Dakota, Iowa, Missouri, and Kansas; University of Montana 2008). Colorado and Iowa have tiered noxious weed lists (e.g. A,B,C or Primary, Secondary) and species from all tiers were included as candidates. From the initial candidate pool of 93 species, I used the Nebraska Natural Heritage Data set (Rolfsmeier and Steinauer 2006) to eliminate 20 species that do not occur in Nebraska (19 of which were listed as noxious in Colorado) and 7 species which are native to Nebraska (including species listed as noxious in Kansas, Colorado, Wyoming, and Iowa). I also eliminated 10 species that were not evaluated by the Naturserve I-Rank assessment (Naturserve 2008). The final list of species to be evaluated includes 56 non-native plants (Table 4). Common and scientific names were adopted from the Weed Science Society of America (WSSA) Composite List of Weeds (WSSA 2010). The US Department of Agriculture (USDA) PLANTS database (USDA 2013) was used to identify synonyms and any names not recognized by WSSA (2010).

A. Adapting the I-Rank Assessment to Nebraska

Individual Non-Native plant species were assessed for a the specified region of interest (Nebraska) to determine an Invasive Species Impact Rank (I-Rank) that categorizes the species' potential for negative impact on natural biodiversity as high (HIGH), medium (MED), low (LOW), or insignificant (INSIG), or a range of these impact categories. In this framework, non-native species are defined as “those present in a specified region only as a direct or indirect result of human activity” (Morse et al. 2004). The I-Rank Invasive Species Assessment Protocol consists of two yes-no screening questions and 20 weighted multiple-choice assessment questions, which are grouped into four sections (referred to as Subranks) that address major aspects of an invasive species' total impact (Appendix B). Factors which tend to raise the I-Rank (towards high impact risk) are the ability to change ecosystem processes, ability to invade relatively undisturbed ecological communities, ability to cause substantial impacts on rare or vulnerable species or ecological communities, wide distribution, high abundance, ability to disperse to new areas readily, and difficulty of control. This information can be used to prioritize species for management decisions, such as further monitoring, additional research, or consideration for listing on the NIS Watch List.

In addition to the 20 weighted multiple-choice assessment questions, the I-Rank Invasive Species Assessment contains two yes-no screening questions. The two screening questions are: (1) Is the species established in the region of interest? (2) Is the species present in native species habitats? Since I only selected species that are documented in Nebraska (Rolfsmeier and Steinauer 2006), and all species are known to occur in

conservation or natural areas based on Natureserve I-Rank screening questions (Natureserve 2008), all 56 species meet both screening questions as required by the I-Rank protocol (Morse et al. 2004).

The I-Rank framework is adaptable to any geographic area, as long as it meets certain criteria (Morse et al. 2004). The geographical region of interest should be large enough to: (1) be dominated by within-region dispersal of species, as contrasted with dispersal across the region's boundaries, (2) have persisting internal habitat diversity and biogeographic patterns, and (3) require multiple serial dispersal events for a species to become widespread within the region of interest. Also the area must be contiguous and have a substantial proportion of internal area in contrast to edge. I evaluated the criteria suggested by Morse et al. (2004) and determined that the state of Nebraska met the requirements. I used the steps suggested by Morse et al. (2004) to modify the framework to a specific area (Table 5). Where appropriate, I developed Nebraska-specific definitions for answers to the multiple choice questions. The individual responses to the 20 adapted questions correspond to point values used to calculate the overall I-RANK (Appendix B). If an exact answer cannot be determined for a question, an answer range is acceptable. In fact, it is not necessary to answer all 20 questions to assess a species. Determining the I-Rank is "polythetic... drawing upon an overall fact pattern that does not require any pre-specified set of individual questions to be addressed" (Morse et al. 2004). When questions are answered with an answer range (e.g., LOW-HIGH), the species' minimum and maximum point totals are individually tallied within each Subrank. The Subranks are similarly combined using separate minimum and maximum point totals to calculate the overall I-Rank. This method allows uncertainty to be incorporated into individual

questions, proliferate through the risk assessment, and be quantified in the final results (Figure 4).

The I-Rank questions within each Subrank are weighted. Likewise, each of the four Subranks are weighted to determine the plant's overall I-Rank designation. The weights assigned for each of the 20 questions and the four Subrank components to the I-Rank are designed to reflect their overall importance in determining a plant's invasiveness. Randall et al. (2008) reports that scoring and comments from a panel of over 100 volunteer evaluators with biological and management expertise for a subset of species were used to calibrate relative weights of the four Subranks and questions within each Subrank. I adopted all question scoring and Subrank weighting from Morse et al. (2004), as detailed in the Subrank Scoring System (Table 6) and I-Rank Scoring System (Table 7).

The 20 weighted multiple-choice assessment questions are grouped into four Subranks that address major aspects of overall likelihood of impact: ecological impacts (five questions), current distribution and abundance (four questions), trends in distribution and abundance (seven questions) and management difficulty (four questions). I will give a brief synopsis of each Subrank, describe methods for defining questions and answer criteria, and describe methods for evaluating answers for each question. The primary sources of data used for completing the Nebraska I-Rank assessments are listed in Table 8. Answer criteria and scoring details for each question are listed in Appendix B.

The data used to complete the Nebraska I-Rank risk assessment were obtained from numerous sources and were incorporated into the I-Rank framework using 3 analytic

processes: Geographic Information Systems (GIS) analysis, expert opinion surveys, and literature review. GIS analysis was performed in ArcGIS after compiling all data in appropriate format to allow assessment of certain I-Rank questions. I used shapefiles for EPA Level 3 Ecoregions (n=6) and EPA Level 4 ecoregions (n=29) to define ecological systems in Nebraska (Chapman et al. 2001). County level occurrence data from The Flora of Nebraska (Kaul et al. 2006), Atlas of the Flora of Great Plains (Barkley 1977), and USDA PLANTS database (USDA 2013) were entered into a County polygon shapefile. Georeferenced data for occurrences of Nebraska Noxious Weeds (NDA 2008) and Nebraska Invasive Watch List species (NWCA 2008b) were imported into the ArcGIS environment to supplement county level records. These data originate from weed inspection reports, and the NWCA Web Tool for georeferencing these reports has increased the availability of this valuable monitoring data (NWCA 2008b). I also georeferenced occurrence records for non-native plants from the Nebraska Game and Parks Commission Inventory of Parks Division Lands (Rolfmeier 2001).

Numerous professionals in Nebraska possess valuable knowledge and experience related to non-native plants. To leverage this valuable information resource, I solicited expert opinions in the form of standardized surveys (Appendix C). Of the 13 expert opinion surveys sent to botanists, land managers, and rangeland specialists with expertise/knowledge of non-native plants in Nebraska, I received eight responses (Table 9). Each expert was asked to rate species for each of three questions giving a letter answer (or range of answers if there is uncertainty) corresponding to High, Moderate, or Low Significance, or Insignificant. The respondents were asked to only answer questions if they have sufficient knowledge of that species, otherwise they were instructed to leave

questions blank. I analyzed completed survey questions by converting answers from letters to a numerical scale corresponding to four possible answers [Insignificant (1), Low (2), Moderate (3), and High (4)]. I kept separate records for upper and lower answer estimates. I analyzed the converted numerical survey response values using summary statistics, which I used to assist in determining answers by process of elimination. All comments received were recorded for each species.

In my experience, the NWCA Weed Management Area Supervisors provide a wealth of information. The subject of non-native plant species is the focus of their full-time job, and these professionals are passionate about protecting ecological and agricultural resources. They are also an invaluable resource in Nebraska for monitoring and early detection because they are our “boots on the ground” in the battle against invasive species throughout Nebraska’s 93 counties. To utilize this wealth of information, I sent out a separate group of surveys to Weed Management Area Supervisors. The questions and methods were identical to the statewide surveys with one notable exception; respondents were asked to confine their answers only to their respective Weed Management Areas (see Figure 1). Of the 13 Weed Management Area surveys responses solicited, I received eight completed surveys (Table 9).

B. Evaluating the 20 I-Rank Questions

The I-Rank questions presented below are grouped by Subrank and then by data source used to answer the questions. I provide a brief description of the concept relating each Subrank to overall I-Rank. For each group of questions, I provide methods and justification for utilizing the information to perform the Nebraska I-Rank assessment,

noting modifications, data, and methods used to answer the questions. All questions were answered using a logic based process of elimination by first scrutinizing the totality of information available for a given species, and then drawing conclusions. In other words, all questions started with the default answer of unknown (INSIG-HIGH), and were then refined down to the smallest possible answer range by eliminating answer classes, based on the information available for each species. In cases where data sources were in conflict and gave different answers, I allowed for uncertainty by retaining both possible answers.

1. Subrank I (Ecological Impact)

Subrank I has five questions and is focused on identifying species with the greatest negative impacts on native species, communities, and ecosystems (Morse et al. 2004). I used the data from the Natureserve I-Rank analysis (Natureserve 2008) to answer Questions 1-5 (Appendix B). The Natureserve analysis was evaluated using data from the contiguous United States (48 states). Local impacts are not known for many of the species and it is difficult to predict impacts for species that are not currently invasive in Nebraska. Furthermore, one of the best predictors of invasiveness for a given species is its history of invading and impacts in other areas (Skinner et al. 2000). I felt that using this data was justified because it was evaluated for a range of settings across the contiguous United States (including Nebraska) and because the I-Rank method is adept in dealing with uncertainty.

2. Subrank II (Current Distribution and Abundance)

Subrank II is based on the concept that the greater the range of a species in a region, and the more ecological regions or habitats that it invades there, the greater the overall damage it can cause. I used county level and point occurrence data (Kaul et al.

2006; USDA 2013; NDA 2008; NWCA 2008b; Rolfsmeier 2001; Barkley 1977) to estimate the current generalized geographic range for each species (Question 6; Appendix B). The generalized range is defined as the “area where the species is present within the region as a non-native outside cultivation, not just the range where it has its greatest impacts, and is usually much greater than actual acreage infested,” (Morse et al. 2004). The precise generalized area would be difficult to calculate using only county level distributions maps. Fortunately, I only needed to classify generalized range into one or more of four broad categories (Appendix B). I calculated the *estimated* generalized range by analyzing occurrence data in GIS software and summing the area of all counties in Nebraska with known occurrences for each species. I also included counties for which occurrences were known for at least three directly adjacent counties because, according to Kaul et al. (2006), it is often safe to assume that a species occurs in a county with no collections amongst many counties with collections present.

I used this estimate to eliminate answers based on the designated criteria (Appendix B). For example, if the *estimated* generalized range = 11%, I eliminated INSIG (< 0.1% of the area of Nebraska). Also, I deemed it unlikely that the generalized range would be >30%, and therefore I eliminated HIGH. In this case the answer would be left as LOW to MED (corresponding to a generalized range between 0.1 and 30 percent of Nebraska). However, in cases where the *estimated* generalized range was greater than 20%, I kept “HIGH” as a possible answer.

Question 7 is designed to determine the approximate proportion of the Nebraska generalized range occupied where the species has significant abundance/impacts (Appendix B). Generalized range is defined as the entire generalized range where the

species is present within Nebraska as a non-native outside cultivation, not just the range where it has its greatest impacts (Morse et al. 2004). I utilized the statewide expert opinion surveys to determine answers to this question (n=8). In addition, I considered the whole of answers from the weed management area surveys (n=8) as an additional statewide expert opinion when determining the final answer for Question 7.

I selected EPA Level 3 Ecoregions (Omernik 1995) to represent “Biogeographic Units” (Question 8) and EPA Level 4 Ecoregions (Omernik 1995) to represent “Habitats or Ecological Systems” (Question 9; Appendix B). I selected EPA Ecoregions for several reasons. First, ecoregions are well defined geographically and can be analyzed in GIS. Ecoregions are defined as “areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources,” (Omernik et al. 2000). They were specifically designed to serve as a spatial framework for the assessment of ecosystems. The delineations are based on patterns of biotic and abiotic phenomena (e.g. geology, physiography, vegetation, climate). Furthermore ecoregions are hierarchical so they will allow comparison of species current distributions at two nested scales.

For Questions 8 and 9, I used county level and point occurrence data (Kaul et al. 2006; USDA 2013; NDA 2008; NWCA 2008b; Rolfsmeier 2001; Barkley 1977) to estimate the number of ecoregions invaded. I analyzed the occurrence data using GIS software to determine the minimum and maximum number of Level 3 and 4 ecoregions where the plant is present in the Nebraska (Figures 5 and 6). If a county record was shared between two or more ecoregions, I considered all possible occurrence patterns (i.e. occurs in any combination of ecoregions within that county). In other words, for each species I performed two counts: one count for minimum number of ecoregions possible,

and one count for maximum number of ecoregions possible given the available occurrence data. I then used the minimum and maximum counts to assign answer ranges based on the answer criteria by a process of elimination.

3. *Subrank III (Trend in Distribution And Abundance)*

Subrank III is based on the concept that high potential for range expansion should increase risk of impacts for potentially invasive species. This Subrank encompasses observed changes in distribution/abundance, dispersal/reproductive ability, and likelihood of invasion.

Question 10 is designed to determine the current trend in range expansion of the Nebraska generalized range for each species (Appendix B). Generalized range is defined as the entire generalized range where the species is present within Nebraska as a non-native outside cultivation, not just the range where it has its greatest impacts (Morse et al. 2004). I utilized the statewide expert opinion surveys to determine answers to this question (n=8). In addition, I considered the whole of answers from the weed management area surveys (n=8) as an additional statewide expert opinion when determining the final answer for Question 10.

Question 11 (Proportion of Potential Range Currently Occupied) was difficult to answer because it requires predicting a potential range, which is based on factors such as habitat requirements, physiological tolerances, and characteristics of the receiving environment. I used the approach of eliminating answers when possible based on literature review, survey comments, and estimated range size ascertained in question six. For example if a species has already achieved a state-wide distribution, I assumed an

answer of LOW (Appendix B). Otherwise, if I was unable to eliminate any answers, the question was scored as Unknown (INSIG-HIGH).

For Questions 12, 14, and 16 (Appendix B), I used the data from the larger scale (contiguous United States) Natureserve I-Rank analysis (Naturserve 2008). These questions deal with a plants ability to disperse, reproduce, and invade mature vegetation. Although, these characteristics are not necessarily location specific, differences occur across environmental gradients. However, since the Natureserve study area included Nebraska, I assumed that adapting these data for Nebraska was acceptable.

Question 13 is designed to determine whether areas of localized range expansion or increased abundance occur within the Nebraska generalized range for each species (Appendix B). I used the expert survey data to answer this question, using methods similar to Questions 7 and 10, with one notable exception. For this question, I gave special credence to WMA surveys because the question deals with localized areas of range expansion and abundance. Therefore if a particular WMA survey indicated an answer as higher significance than the range of answers from the other surveys, I kept it as a possible answer. For example, if statewide and most WMA surveys indicated an answer of LOW but one weed management area answered as HIGH, I scored the question as LOW-HIGH.

I adapted Question 15 (Similar Habitats Invaded Elsewhere) to read, “Of the six EPA Level 3 Ecoregions that occur in Nebraska, how many Ecoregions have plant occurrences outside of their Nebraska portion?” I used a GIS coverage of full extent of the six EPA Level-3 Ecoregions that occur in Nebraska (Figure 5) and county maps to

analyze ecoregions outside of Nebraska where the species occurs. I used county level occurrence maps (USDA 2013; Barkley 1977) and minimum/maximum Ecoregion count methods, as described for Questions 8 and 9, to determine answer ranges for each species.

4. *Subrank IV (Management Difficulty)*

Subrank IV is based on the concept that species that are difficult to control have higher impact potential. This Subrank also includes considerations for difficulty due to accessibility of invaded sites and potential for collateral damage to native species due to control methods. For Questions 17-20 (Appendix B), I used the data from the larger scale (Contiguous United States) Naturserve I-Rank analysis (Naturserve 2008). These questions deal with level of difficulty in controlling plants due to cost, time commitment, collateral damage from control on native species, and accessibility of invaded areas. Because the answers for the Naturserve I-Rank assessment were evaluated for the contiguous U.S., including Nebraska, I assumed that is acceptable to use these answers for the Nebraska I-Rank assessment.

C. Determination of Subranks and overall I-Rank

All methods of calculating Subrank and I-Rank classes are based on the 20 question score data and are identical to those in Morse et al. (2004). Upper and lower Subrank classes were calculated by separately summing the upper and lower answers for all questions within each subrank, based on the assigned point values (Appendix B). For each of the 20 questions, the four answers are proportionately scaled with answers HIGH, MED, LOW, or INSIG corresponding to letter answers A, B, C, and D. Point values for the four answers are accordingly assigned in the proportion 3:2:1:0, respectively

(Appendix B). Answers from the questions for all 56 species were organized into a database which was used to calculate Subranks (Table 6). The four resulting Subranks (either a single Subrank class or a range of Subrank classes) are in turn used to determine the overall I-Rank (Table 7). The Subranks are assigned their own relative weight factors, which are designed to reflect their relative importance in predicting species' overall impact on biodiversity (Morse et al. 2004). Each Subrank class is assigned points in the proportion of 3:2:1:0 for Subranks of HIGH, MED, LOW, and INSIG, respectively. The upper and lower I-Rank classes are determined by separately summing the numerical values associated with the upper and lower Subrank classes (Table 7). The result can be a single overall I-Rank class (e.g. HIGH) or a range of classes (e.g. LOW-MED).

D. Methods for Quantifying Uncertainty

An important issue to understand when interpreting I-Rank results is that the point system used to enumerate question results, calculate Subranks, and determine overall I-Rank operates on an ordinal scale. An ordinal scale is defined as having mutually exclusive and ordered classes (e.g. low, medium, and high blood pressure), whereas a categorical variable that has no logical order is referred to as nominal or qualitative (e.g. rock, bluegrass, and classical music) and continuous variables often operate on an interval scale (e.g. temperature in degrees Fahrenheit). As a consequence, selection of appropriate statistics to summarize and interpret ordinal data is restricted due to underlying statistical assumptions. For example, when seeking to quantify variation (i.e. dispersion or spread), the use of standard deviation is inappropriate for ordinal data (Jamieson 2004). Although there are limitations, Agresti (2010) points out several advantages when compared to nominal data, because ordinal data are inherently

quantitative, with each level referring to “a greater or smaller magnitude of a certain characteristic” than another level. Ordinal data description can use measures such as correlations, slopes, and means (Agresti 2010). However it is not always appropriate to make significance statements about such summary statistics. This is an area of controversy among statisticians (Knapp 1990). Some defend the practice of applying interval scale statistics to ordinal data by regarding the differences between categories as equal (e.g. A minus B is equal to B minus C). I do not make any such assumptions for interpreting I-Rank data.

Although, the I-Rank assessment uses ordinal data, the data can be analyzed by utilizing the numerical point scale (Agresti 2010). I evaluated Subranks to determine levels of variation due to uncertainty and to determine average effect of Subrank uncertainty on I-Rank values. In other words I wanted to quantify the effect of input uncertainty (question answers) on output uncertainty (I-Rank). I wanted to answer three specific questions: (1) what is the degree of variation within each Subrank? (2) How does the variation between Subranks compare after taking the unequal allocation of points among Subranks into consideration? And (3) how does the Subrank variation, a measure of input uncertainty, affect the I-Rank variation, or output uncertainty? I developed three statistic equations to quantify answers to the three questions. I calculated the raw average variation (RAV) for each Subrank as the average difference between upper and lower point totals across all 56 species (Equation 1). Then, I calculated proportionate average variation (PAV) by normalizing the RAV by the maximum point range (MaxRange) within each Subrank (Equation 2). This was done to correct for the unequal number of questions and question weighting within each Subrank. For example, the MaxRange for

Subrank III is 72 (Table 6). Lastly, I calculated the proportion of I-Rank uncertainty (PIU) attributed to each Subrank by multiplying the PAV by the Subrank weight factor (W), then dividing by the summation of PAV times W across all Subranks (Equation 3). The PIU statistic totals to 100% across Subranks and reports about the average effect of each Subrank in determining the I-Rank uncertainty.

E. Equations

$$[1] \quad RAV_j = \frac{\sum_{i=1}^n (U_{ij} - L_{ij})}{n}$$

$$[2] \quad PAV_j = \frac{RAV_j}{MaxRange_j}$$

$$[3] \quad PIU_j = \frac{PAV_j W_j}{\sum_{j=1}^m PAV_j W_j}$$

Where: RAV_j = raw average variation for Subrank j
 U_{ij} = Subrank j Upper Limit for species i
 L_{ij} = Subrank j Lower Limit for species i
 n = number of species evaluated
 PAV_j = proportionate average variation for Subrank j
 $MaxRange_j$ = maximum point range for Subrank j
 PIU_j = proportion of I-Rank uncertainty
 W_j = weight factor for Subrank j
 m = number of Subranks

F. Comparing I-Rank Assessment Results

The Nebraska I-Rank assessment relies heavily upon the data evaluated for the Naturserve (2008) I-Rank assessment, which was evaluated for the United States, excluding Alaska and Hawaii. Therefore, I compared the I-Rank results for each species between the two assessments to determine if the relationship fell into one of four categories: (1) Unchanged- the I-Rank designation for both analyses was identical, (2)

Increased Uncertainty- the range of I-Rank class increased for Nebraska (e.g. LOW to LOW-MED), (3) Decreased Uncertainty- the range of I-Rank class decreased for Nebraska (e.g. LOW-MED to MED), and (4) Shifted- The I-Rank changed but the range, or number of I-Rank classes spanned, was unchanged (e.g. from LOW-MED to MED-HIGH).

G. Methods for Summarizing Results

Finally, to provide a synthesis of information for each species I designed a one-page summary sheet to summarize findings for each species. The sheets contain designations for the four Subranks and overall I-Rank. Notable information garnered from literature review and expert opinion surveys are also provided as commentary. Maps depicting counties with known collections (Kaul et al. 2006) and regulatory status in Nebraska and six surrounding states (University of Montana 2006) are provided as reference. Lastly, I graphed each species with regard to upper and lower point estimates for each Subrank. For purposes of visualization and efficiency, I combined Subranks I (ecological impacts) and IV (management difficulty), and Subranks II and III (current and trend in distribution/abundance) into contrasting XY diagrams. These boxed diagrams allow for a rapid visual assessment of the components of invasion risk associated with each species. The farther the box is positioned towards the Subrank maximums in the upper, right quadrant, the greater the invasion risk associated with that species. In addition, one can readily visualize the overall amount of uncertainty associated with each species. The area of the box formed by the upper and lower estimate lines for both Subranks can be interpreted as the estimated uncertainty for that species (i.e. larger rectangle area= increased uncertainty).

3. RESULTS

The I-Rank and Subrank results for the 56 species assessed are shown in Table 10. Individual species summaries including Subrank diagrams can be found in Appendix D. Of the 56 species assessed, 21 have potential I-Rank Values (upper estimates) of HIGH, 25 are MED, and 10 are LOW or INSIG (Table 10; Figure 7; Figure 8).

The most common I-Rank class was LOW-MED with 13 species (Figure 7). Fifteen species had a single I-Rank class (reflecting low uncertainty), of which HIGH had the most species (6) followed by INSIG (5), MED (2), and LOW (2). Of the 41 species with a range of I-Rank classes, 25 span two classes (e.g. MED-HIGH), 15 span three classes (e.g. LOW-HIGH), and 1 species spanned all four classes (INSIG-HIGH), which is equivalent to “unknown”.

When comparing results from the Nebraska I-Rank to the Natureserve I-Rank assessment (Naturserve 2008), 22 of 56 species I-Rank designations were unchanged. Of the 34 species with a change in I-Rank class, 17 have increased uncertainty, 9 have decreased uncertainty, and 8 species were shifted.

Proportionate average variation (PAV) ranged from 20.4% (Subrank III Trend Distribution and Abundance) to 28.7% (Subrank IV Management Difficulty). Although Subrank IV (Management Difficulty) and Subrank II (Current Distribution and Abundance) had the highest proportionate average variation (PAV), Subrank I (Ecological Impact) had the highest proportion of I-Rank uncertainty (PIU; Table 12).

Of the 21 species evaluated that are on the Noxious and NIS Watch Lists, the upper I-Rank class was HIGH for 14 species and MED for 7 species (Table 11). Seven species not listed on the Noxious or NIS Watch Lists have upper I-Rank class of HIGH (Table 13).

4. DISCUSSION

A. Sources of Error

Prior to interpreting results, there are several potential sources of error and/or uncertainty that should be considered. The potential errors discussed below shed light on underlying assumptions inherent to the I-Rank assessment method and its application for non-native plants in Nebraska.

Using county level occurrence records for scoring I-Rank questions could lead to spurious conclusions. I strived to make conservative estimates of generalized range by using a process of elimination. However, in many cases the county level records do not accurately portray the generalized range of a species due to lack of collections. For example, Kaul et al. (2006) states that chicory (*Cichorium intybus* L.; Appendix D-15) “collections do not reflect its extensive distribution and great abundance.” This was further illustrated by observing that occurrences from monitoring data for listed species (NDA 2008, NWCA 2008b) occurred in counties not depicted by county occurrence maps (Kaul et al. 2006). However, for many species, the county level records were the best species occurrence data readily available. Another source of error inherent in using data from collections is that the generalized distribution is not stable across time. In other words, the absence of a record of a species in a county does not necessarily mean it

doesn't occur there. Conversely, as pointed out by Kaul et al. (2006), the presence of a collection record in a county does not necessarily mean the species still occurs there. Furthermore, some of the data sources utilized have not been recently updated (e.g. Barkley 1977), likely increasing the potential for errors mentioned above. Lastly, any of the sources used to complete the I-Rank assessment may contain error due to mistakes. For example, Kaul et al. (2006) point out that the Barkley (1977) occurrence records for johnsongrass (*Sorghum halepense* (L.) Pers.; Appendix D-54) in northwest Nebraska were erroneous.

The Natureserve data utilized for several of the I-Rank questions were evaluated at a different scale than intended for the Nebraska I-Rank assessment. I justified using this data because the Natureserve area of investigation was the 48 contiguous United States, which includes Nebraska. This has no doubt led to increased uncertainty for these questions, but also has potential for introduction of errors. Ecological and biological/physiological responses vary across a range of environmental gradients. A particular subset of either limiting or increasing environmental conditions could exist in Nebraska, which were not necessarily evaluated by the Natureserve assessment.

Three of the I-Rank questions were answered using expert opinion surveys (n=8) and Weed Management Area surveys (n=8). Although the answers to opinion questions are subjective by definition, several measures are in place to reduce this subjectivity. The I-Rank framework is robust in that it encourages incorporation of uncertainty rather than subjectivity. For example, a survey respondent could select a range of answer classes or decline to answer a question entirely where sufficient data to make such a decision is not available or outside the respondents area of expertise. All answers to each I-Rank

question have specific definitions as opposed to just generalized categories. Lastly, by incorporating opinions from numerous individuals, effects of errors and/or outliers are decreased. Although an increased survey sample size would be desirable, there is a limited pool of people with sufficient expertise to answer the questions solicited. Overall, I was satisfied with the 62% survey response rate.

B. Interpreting and Using the I-Rank

Care must be taken when interpreting results from the I-Rank assessment, with the goal of prioritizing species for further consideration in management decisions. For example, it is not appropriate to consider a hypothetical species X, with an I-Rank value of LOW-MED, as less invasive than some other species Y that has an I-Rank value of MED-HIGH. Rather, given the available information, species Y has a higher probability of becoming invasive and could receive higher priority for any further investigation, monitoring, or management decisions. It also should be recalled that the purpose of the assessment is to identify threats to natural areas (as opposed to agricultural land or other anthropogenic areas). For example, field bindweed (*Convolvulus arvensis* L.; Appendix D-19), a known troublesome weed in cropland, was scored as INSIG-LOW for Subrank I (Ecological Impact). The I-Rank assessment provides information in an accessible format that can serve as a foundation for management decisions. One of the main goals is to differentiate between likely insignificant species and species predicted to have substantial ecological impacts. However, because the I-Rank is semi-quantitative or ordinal in nature, the numeric Subrank and I-Rank point estimates must be interpreted accordingly. For example, a hypothetical species with an I-Rank estimate of 30 points has less

invasion risk than a species with an estimate of 60 points, but not necessarily 50% less risk.

C. Nebraska I-Rank Findings

The Nebraska I-Rank identified 10 species as INSIG, LOW, or INSIG-LOW, indicating they are not likely to become invasive in Nebraska (Table 10). These predictions seem to line up with both survey comments and literature review information (for examples see Appendix D pages 5, 8, 15, 21, 22, 23, 46, 50, 52, and 56). The fact that there is concurrence between results from literature review, survey responses, and the Nebraska I-Rank assessment, suggests that the assessment is performing well in classifying these species.

I-Rank results for several species resulted in somewhat high levels of overall uncertainty, such as INSIG-MED or LOW-MED. These species require a careful interpretation to prioritize, but the Subrank results often prove useful by separating the sources of uncertainty. For example corn chamomile (*Anthemis cotula* L.; Appendix D-6) had a I-Rank result of INSIG-MED for Nebraska. However, when looking at the Subrank diagrams, it is obvious that uncertainty for Subranks I and IV are greatly influencing the results. Recall that these two Subranks were evaluated using the Natureserve I-Rank data, which were evaluated at a much larger scale. The fact that the species is classified as a “waif” in Nebraska (Kaul et al. 2006), indicates that the true estimate for both Subranks I and IV would be on the lower end of the continuum, if evaluated at the state scale. Therefore, given the totality of information available, I would interpret this I-Rank as “effectively INSIG-LOW”. A similar *post-hoc* analysis

should be performed to scrutinize and qualify all I-Rank predictions before making management decisions, re-interpreting I-Rank predictions only if sufficient information exists. Some species had modest levels of uncertainty across all four Subranks. The result is that the additive nature of the I-Rank scoring system caused overall I-Rank predictions to have somewhat high uncertainty (e.g. LOW-HIGH for quackgrass, *Elymus repens* (L.) Gould, Appendix D-26; and INSIG-MED for redstem filaree, *Erodium cicutarium* (L.) L'Hér. ex Ait., Appendix D-27).

Results for plumeless thistle (*Carduus acanthoides* L.; I-Rank= INSIG-HIGH; Appendix D-10) warrant additional discussion. Although the species is listed on the Nebraska Noxious Weed List (NDA 2008), it is the only species evaluated that spanned all four I-Rank classes. The high uncertainty result seems counter-intuitive based on the fact that increased monitoring and reporting should reduce uncertainty. Management Difficulty (Subrank IV) has a high degree of uncertainty when evaluated on a national scale. This uncertainty could be reduced using information from Nebraska for this well-known species. Statewide survey median answer ranges for Questions 7, 10, and 13 were LOW-MED, LOW-MED, and LOW, respectively. WMA median answer ranges for the same questions were INSIG, INSIG-LOW, and LOW. This interesting result indicates that respondents regard the weed as a somewhat low threat, especially compared to other noxious weeds. Survey comments echo these sentiments, noting that plumeless thistle is often out competed by Canada thistle (*Cirsium arvense* (L.) Scop.; Appendix D-16). These results should be interpreted using additional state-level information available for the species. Depending on the results of the additional analysis, which could be

conducted using the I-Rank framework or an informal decision analysis, plumeless thistle could be considered for removal from the Noxious List.

The I-Rank seems to have performed well in identifying potentially invasive plant species in Nebraska. All species that are currently on the Noxious List and NIS Watch List scored at least a Medium for Overall I-Rank upper estimate (Table 11). Seven species not currently on the Nebraska Noxious Weed List or Nebraska Invasive Watch List scored a HIGH for Overall I-Rank upper estimate (Table 13). I examined and interpreted results for these seven species as an exercise in prioritizing recommendations for management decisions. Several factors should be considered when comparing the relative threat of these species. For example, results indicate that downy brome (*Bromus tectorum* L.; I-Rank= HIGH; Appendix A-9) has low uncertainty because it already widespread in Nebraska and its impacts are well documented. Conversely, buckhorn plantain (*Plantago lanceolata* L.; I-Rank= LOW-HIGH; Appendix A-44) has high uncertainty. As mentioned previously, one must look at the Subrank diagrams and evaluate the sources of data and uncertainty. Although SubRank I was classified as LOW-HIGH for buckhorn plantain, observations in Nebraska indicate that the impact to biodiversity in natural areas for this plant, which has been present in the state for over 100 years, would not be accurately described as HIGH. Therefore, I interpret Subrank I as “effectively LOW-MED”, leaving Subrank IV as the only component with the possibility of HIGH. Recall that the Subrank IV relative weight factor (W) is 0.10 or 10% of the overall I-Rank. I would therefore rule out HIGH as an overall I-Rank class, and interpret the species as “effectively LOW-MED.” A similar rationale could also be used to interpret yellow starthistle (*Centaurea solstitialis* L., Appendix D-13) as “effectively

LOW-MED” for I-Rank in Nebraska. Therefore these two species would be prioritized below the other species listed in Table 13. Although I have made these interpretations as an example, I still present the actual output from the Nebraska I-Rank assessment in Table 13. Stakeholders or managers, such as members of the NIS Watch List Committee, may have different interpretations and insight to take into consideration. The other species listed in Table 13, did not have information suggesting that modification or re-interpreting I-Rank predictions was appropriate. Therefore, for this example, species would be prioritized in the order shown in Table 13.

Another factor to consider when making decisions or prioritizing is the relative cost/benefit ratio of attempting various management strategies (Hiebert and Stubbiendick 1993). The species with highest priority would have HIGH Impact, LOW Management Difficulty, LOW Current Distribution/Abundance, and HIGH Trend in Distribution/Abundance. In other words, species likely to impact biodiversity that are not currently widespread, but which are spreading rapidly, and have a feasible means of control/prevention should be the highest priority. For example, downy brome (*Bromus tectorum* L.; Appendix A-9) is so widespread in Nebraska that attempts to eliminate it are probably not feasible. Therefore, listing downy brome on the NIS Watch List would likely have limited utility.

The comparison of Natureserve I-Rank and Nebraska I-Rank assessment results yielded interesting findings. Of the 34 species with changed I-Rank classes, 17 have increased uncertainty, 9 have decreased uncertainty, and 8 have shifted classes. This reinforces the concept that answers to ecological questions are often scale-dependant, which has been demonstrated in numerous studies seeking to predict species occurrences

(Scott 2002). The fact that 61% of species evaluated had results that differed between the Nebraska and Natureserve I-Rank assessments is also significant given that 12 out of 20 Nebraska I-Rank questions were answered using the Natureserve (2008) data. The 17 species that had increased uncertainty indicate that some questions are more easily answered when evaluated at a coarser scale. However, nine species had decreased uncertainty indicating more complete information for some species at the state level.

Another example of the scale-dependant nature of ecological predictions is that the PRIDE WMA survey answers and comments indicated appreciably higher risks than other areas of the state for several species including Russian knapweed (*Acroptilon repens* (L.) DC., Appendix D-3), common burdock (*Arctium minus* Bernh.; Appendix D-7), downy brome (*Bromus tectorum* L.; Appendix D-9), and houndstongue (*Cynoglossum officinale* L.; Appendix D-20). Located in the northern panhandle (see Figure 1), the PRIDE WMA occurs at the Nebraska extremes for elevation (high), precipitation (low), and latitude (high). The area also has unique native plant communities, such as “Ponderosa Pine Forests and Savannah” (Kaul et al. 2006). Therefore, it should not be surprising that certain non-native species are more successful at invading in this area when compared to the rest of Nebraska. Just as results from the Natureserve (2008) 48-state I-Rank assessment need careful interpretation at the state level, Nebraska I-Rank results should be re-interpreted for decisions at the regional or local level.

When comparing Subrank uncertainty, Subrank IV (Management Difficulty) had the highest proportionate average variation (PAV), which I interpret as highest input uncertainty (Table 12). This result seems logical because Subrank IV was evaluated using national-scale data, and because controlling weeds will require greater effort in certain

locations depending on several factors such as abundance. For example, kudzu (*Pueraria montana* var. *lobata* (Willd.) Maesen & S.M. Almeida, Appendix D-46) is likely much easier to control in Nebraska (at the extreme north of its climate tolerance) than in the southeast United States where it is a serious weed (Stubbendieck et al. 2003). Also, control methods for many lesser known invaders have not been well studied. Another facet worth mentioning is that much of the knowledge for management of “weed” plants (including control by herbicides etc.) results from agricultural research where the goal is often a monoculture of crop species, whereas the goal in natural areas is often native diversity. Although management difficulty (Subrank IV) has the highest input uncertainty, the proportion of I-Rank uncertainty (PIU) attributable to this Subrank is only 13% of the total output uncertainty. Nonetheless, overall I-Rank status for individual species is sensitive to uncertainty in Subrank IV (see mayweed chamomile, *Anthemis cotula* L., Appendix D-6). Subrank II (Current Distribution/Abundance) had the second highest input uncertainty. This can be attributed to primarily using county-level records for determining distribution patterns.

Not surprisingly, the pattern of proportion of I-Rank uncertainty (PIU) for each Subrank approaches the Subrank weight factor (W). This points out that the I-Rank class predictions and associated uncertainty is highly sensitive to weight factors assigned to each Subrank. Randall et al. (2008) reported that Subrank weight factors were assigned by calibrating the I-Rank class predicted with numerous expert opinions. Although I adopted the weight factors used by Randall et al. (2008), several stakeholders have commented that they would prefer a higher Subrank weight factor for management

difficulty. This could be accomplished by slightly reducing the subrank weight factor for Ecological Impact.

Overall the I-Rank method is a worthwhile risk assessment protocol. Obviously, it does not provide a final definitive answer, but it does provide valuable information and an objective way to prioritize potentially invasive species. Some of the data required for completion of the risk assessment are not readily available. I solicited expert opinion for three questions when I was not able/qualified to make such determinations. Designing and implementing an expert opinion survey may not always be a viable option. However, I was fortunate to have the participation and interest of several experts in the state. Although the expert opinion information was not necessarily crucial to complete the I-Rank assessments, it substantially reduced the uncertainty in the I-Rank results. If advantageous for a particular area, it would be possible to use a tiered I-Rank assessment by first using all readily available information, then prioritizing and researching more information for certain species. The key strengths of the I-Rank assessment are that it allows incorporation of data from multiple sources, it is flexible based on the research needs and data availability, and it allows for uncertainty. This flexibility allows for assessment of well known species for comparison with lesser known non-native species. The framework is also fully customizable for specific areas, situations, and scales.

The I-Rank has some relative weaknesses that should be mentioned. The questions operate on a broad scale and are not useful for predicting invasions at specific locations. Also, some questions are difficult/subjective to answer. For example, Question 11 (Proportion of Potential Range Currently Occupied) is very difficult to answer in some cases. Often, the potential range is not known because the species has recently been

introduced and it is not known where it could invade. The most complete data was sought for all questions to eliminate subjectivity. However, at some point a decision must be made to answer a question based on the totality of information available. Despite my best efforts to remain conservative in eliminating answers, a limited number of subjective decisions had to be made to determine an answer range. Fortunately, the I-Rank draws information from so many sources that any potential errors have less impact on the polythetic fact pattern (Morse et al. 2004). Although informative about risk, the I-Rank assessment cannot predict the “worst” invaders or which new species will become exceedingly invasive.

Due to the ordinal nature of the I-Rank data, the assessment is not adept at quantifying statistical significance or hypothesis testing. Also, when selecting appropriate summary statistics one must be careful to not violate underlying statistical assumptions (Jamieson 2004). Agresti (2010) provides several methods of analyzing ordinal data, including methods of quantifying the unobserved continuous latent variable. However, the strength of I-Rank in dealing with uncertainty leads to a weakness drastically complicating statistical inference. The fact that the I-Rank results can be a range of classes, make classification accuracy tests (such as Cohen's kappa coefficient statistic) problematic. This potential weakness should be considered in light of I-Rank strengths and research needs before selecting this method.

D. Conceptual Framework for I-Rank Assessment

I think it is important to relate the I-Rank framework to the risk assessment concept (Figure 2). Recall that risk assessment for invasive species involves quantifying

likelihood and uncertainty for two components: exposure to a stressor (probability of invasion), and effect to a response endpoint (severity of ecological impacts). Stated another way: risk = (invasion probability x impact severity) \pm uncertainty. I propose that the paired Subrank diagrams (Appendix D) allow for a rapid visual assessment of likelihood and uncertainty results, while also providing a useful conceptual context. Consider that Subranks II and III (current and trends in distribution/abundance) are quantifying potential exposure to an invasive species. Furthermore, consider that Subranks I and IV (impact and management difficulty) are quantifying severity of impacts, due to ecological impacts, economic impacts (as measured by management difficulty), and collateral damage to native species due to eradication efforts (for example see comments for musk thistle, *Carduus nutans* L., Appendix D-11). Using this context, one can adapt the risk assessment concept (Figure 2) to the I-Rank risk assessment framework (Figure 10). I conclude that this conceptual framework can enhance understanding and communication of results.

5. ECOLOGICAL NICHE MODEL FEASIBILITY STUDY

A preliminary study was performed to determine the feasibility of using Ecological Niche Models (ENM) to decrease uncertainty in I-Rank predictions for a subset of species. For example, an ENM approach could be used to predict distributional areas for non-native plants in Nebraska. Interpreting results from this spatial approach could reduce uncertainty for the I-Rank assessment for species where the potential range is not known. The model predictions could be evaluated/interpreted using independent

records of successful invasion. There are several considerations for ENM that determine the appropriate application of these methods.

Several ecoinformatics approaches (such as classification trees, artificial neural networks, and genetic algorithms) have advantages over traditional ecological models (such as regression techniques), which are often limited because of assumptions of normality, obligatory transformations, and ineptness with few or more zero values. Ecoinformatics models are not as limited by these drawbacks and have consistently outperformed traditional approaches when analyzing equivalent non-linear data sets (Lek et al. 1996; Olden and Jackson 2001; 2002). Informatics techniques comprise a wide range of approaches but are generally defined as advanced computational models that can learn from experience (training) and generate increasingly accurate models based on some measure of performance. The models are also stochastic in nature, meaning models created with the same input data will differ to some extent based on random effects.

Classification trees (CART) use a set of predictor variables to predict a single categorical response variable by repeatedly splitting the data into groups (nodes) of increasing homogeneity, or binary recursive partitioning. CART models are often straightforward, in that they require minimal knowledge of variable relationships. Several advantages of CART for ecological applications have been recognized including: flexibility for numeric or categorical dependant variables, capacity to explore data interactions, and easy graphical interpretation due to the intuitive hierarchical representation of classification rules (Death and Fabricius 2000). CART analysis has a number of advantages over other statistical methods that make it particularly suitable for modeling ecological data. These include the fact that CART is: (1) inherently non-

parametric and therefore makes no assumptions regarding the underlying distribution of the data, (2) invariant to monotonic transformations of the data, and therefore eliminate the objectivity and subjectivity of data transformations, (3) able to handle mixed numerical data including categorical and continuous variables, (4) able to deal with missing variables by using the surrogate splitting variables in the decision tree, and (5) relatively simple for non-statisticians to interpret. CART is being increasingly used in the analysis of ecological data, including predictions of species presence/absence (O'Connor et al. 1996; Olden and Jackson 2002), abundance (Mankin and Warner 1999; Rejwan et al. 1999), community richness (Magnuson et al. 1998), and invasion threat (Reichard and Hamilton 1997).

Based on the advantages and desirable attributes discussed above, I selected CART models to develop preliminary models for non-native plant species in Nebraska. Initially, my intent was to select a subset of species based on results of the I-Rank assessment. However, it quickly became apparent that a major limiting factor in selecting species for ENM was occurrence data availability. A limited number of occurrence data for some species was available in internet-accessible museum databases. However, I determined through literature review that a minimum of 30 to 50 occurrence records would be necessary to generate satisfactory models. Subsequently, I discovered a source of detailed and numerous location data in an atlas describing medicinal plants of the Soviet Union (Chikov 1976). Based solely on data availability and inclusion in the Nebraska I-Rank Assessment, six species were selected for the preliminary ENM: garlic mustard (*Alliaria petiolata* L.), absinth wormwood (*Artemisia absinthium* L.), common St.

Johnswort (*Hypericum perforatum* L.), European Buckthorn (*Rhamnus cathartica* L.), common tansy (*Tanacetum vulgare* L.), and common mullein (*Verbascum Thapsus* L.).

The next step was to compile data for the ENM. Both presence and absence data are required to make niche predictions. I scanned the highly detailed maps from Chikov (1976) and georeferenced the high-resolution images using ArcGIS. The known presence points for each species were then digitized in the ArcGIS environment to capture their precise location. Since true absence data was not available and is often suspect, I used a pseudo-random approach to generate absence data (Zarnetske et al. 2007; Engler et al. 2004; Lutolf et al. 2006; Olivier and Wotherspoon 2006). All GIS analysis was performed separately for each species. First, a shapefile containing all country polygons where presence data was identified was created. Then, I created a 0.5 decimal degree buffer around all presence points and clipped (removed) the buffered areas from the countries shapefile. Absence data points were then generated within this remaining area using a random algorithm. To determine the number of absence points, I used a 1:1 ratio for presence:absence data (Zaniewski et al. 2002). Next, I compiled suitable environmental data for predicting species native and non-native ranges. I researched digitized environmental variables available on a worldwide coverage, and selected variables that could be factors in determining niche space for plants (Table 14). I re-sampled all raster data to 0.1 decimal degree (dd) pixel size before analyzing.

I selected the See5 classification tree software for generating CART models (Rulequest 2008). See5 has been used in numerous and diverse applications for CART models. See5 also uses a procedure called boosting which has been shown to improve the results produced from classification trees. However, selection of this particular software

was largely based on a recommendation and the availability of a mapping tool for creating spatial representations of the CART models. The NLCD Mapping Tool (MDA 2006) was specifically designed to develop spatial classification maps and confidence probabilities for raster data based on See5 model predictions.

There are a number of parameters within See5 that have the potential to greatly affect model results. For example, the percent pruning parameter affects the way that error rates are estimated. The severity of tree pruning therefore influences the number of nodes in classification trees models, with potential to overfit the model. Another software option is applying differential classification costs for false positive and false negative errors. Numerous other parameter options exist within See5, such as training/test data percentages, attribute winnowing, boosting, cross-validation, and confidence levels for pruning (Rulequest 2008).

Preliminary results from ENM trials indicate the See5 CART models are sensitive to selection of parameters described above. A simulation of 1000 model runs was performed for various levels of %pruning to determine the effect on model prediction accuracy using independent test data. A similar experiment was devised for evaluating effects of specifying differential classification costs. Unfortunately, See5 is not set up for fully automated simulations and the above analysis required various model outputs to be manually pasted into a spreadsheet for comparison, a very time-consuming process. Furthermore, although the UNIX version of See5 has a batch mode, it still requires manual entry of the various parameters rather than allowing for a range of values and simulations to be run. This software shortcoming did not allow for full exploration of the various other parameters mentioned above, therefore See5 default values were used.

Finally, I ran 100 models for each species using optimal values for %pruning and differential classification costs, obtained from the parameter analysis trial results. I selected the 10 best model sets for each species by analyzing performance based on commission and omission errors (Bell 1999).

Another shortcoming that should be mentioned is that the NLCD Mapping Tool (MDA 2006) did not function as anticipated. In fact, throughout a lengthy process of trial and error, the software never succeeded in projecting a spatial representation of See5 model predictions. The problem is that the tool requires pixel size, file parameters, projections, and extents to be identical. I attempted numerous methods of re-sampling the environmental data with no success. I contacted one of the collaborators that worked on the NLCD Mapping Tool, who confirmed my suspicions that the tool is problematic in dealing with datasets combined from various sources. The tool will give an error message when any of the above-mentioned parameters is off by as little as 0.00000001, the tool is “completely unforgiving” (Michael Coan, personal communication). I was finally able to get a spatial representation of model predictions through a lengthy conversion process by treating all pixels as point data and using See5 software to predict the “points”, bypassing the NLCD Mapping Tool completely.

Results from projecting the ten best model sets onto the non-native range (environmental data clipped to an area approximating the Great Plains Region) indicated some problematic observations. Several model sets indicated low likelihood in areas of known occurrences. Furthermore, individual models within the 10 model sets varied widely in their predictions. Although the models are stochastic, the low level of agreement between models implies low confidence in model performance and utility. A

more rigorous exploration of See5 model parameters and their affect on spatial representations of model predictions should be conducted before incorporating ENM for this application. Unfortunately, the software limitations described above precluded conducting the proposed analysis in an efficient way. Based on the feasibility study, ENM was not incorporated into the I-Rank assessment for Nebraska. However, ENM remain a potentially viable method for reducing I-Rank uncertainty.

6. CONCLUSIONS

A. Improvements and Future Studies

Based on the results of this research, several opportunities exist for advancement in this line of research. Results from any predictive model are sensitive to model parameters. The PAV/PIU comparison shown in Table 12 demonstrates that predicted I-Rank class and uncertainty are very sensitive to the Subrank weight factors (W). A meta-analysis on the effects of changing Subrank or question weight factors could yield useful results in refining the method. Analyzing which questions are most important in determining likelihood of impacts could also yield interesting and useful results. Many stakeholders commented they would prefer a higher Subrank weight factor for management difficulty. This and other modifications to I-Rank parameters seem to be feasible, but should be based on some defensible and/or quantitative method, ideally using comprehensive data for a large number of well-studied species.

A preliminary version of this research was presented to the NIS Watch List Committee and the species listed in Table 13 were presented and discussed as potential candidates for addition to the list. Subsequently, two new species were added to the NIS

Watch List, sulfur cinquefoil (*Potentilla recta* L.; I-Rank= LOW-HIGH, Appendix D-45) and perennial pepperweed (*Lepidium latifolium* L.; I-Rank MED-HIGH, Appendix D-35). As a result of being added to the list, focused monitoring and reporting for these species should increase. An interesting study might be to re-evaluate the I-Rank assessment for these species in the future. Increased monitoring for these species will produce additional data. Theoretically, the uncertainty should be reduced and a decision could be made to remove the species from the list, elevate to noxious status, or retain on the NIS Watch List. Figure 9 provides a conceptual context, showing how monitoring contributes to a management framework by reducing uncertainty and assisting in decision-making.

A tiered approach should be considered for future I-Rank assessments. For example, a minimal number of questions could first be answered using the most straightforward and readily available data. This process could reduce the candidate pool for the next tier of assessment by removing species designated as INSIG/LOW or HIGH, because additional information is not needed to make a decision. Alternatively, if one wanted to perform a more comprehensive assessment than that presented here, additional information such as state-level analysis for all I-Rank questions or predictive spatial models could be incorporated. By integrating an Ecological Niche Model (ENM) component, I-Rank uncertainty for lesser known or newly introduced species could be reduced. As mentioned previously, Question 11 (Proportion of Potential Range Currently Occupied) was the most difficult question to answer, especially for species with limited distributions in Nebraska. Determining an answer often requires predicting a potential range based on factors such as habitat requirements, physiological constraints, and

numerous biotic and abiotic characteristics of the receiving environment. ENM have shown the ability to make such predictions, which could then be compared to the current estimated generalized range to better infer about the proportion of potential range currently occupied.

B. Final Conclusions

The I-Rank assessment provides information in an accessible format that can serve as a foundation for invasive species management decisions. However, the scale at which the I-Rank questions are evaluated should be considered before making management decisions. While some questions are easier to answer at a national scale, other questions may have more complete information available when evaluated at a state or regional scale for certain species. A tiered I-Rank approach would provide distinct advantages by first identifying species that require additional research, then analyzing additional information to reduce I-Rank uncertainty. If a formal tiered approach is not utilized, results should be interpreted with respect to smaller-scale information available for each species.

Sources and quantities of I-Rank uncertainty should be studied before making management decisions for each species. A distinct disadvantage of the I-Rank method is that quantitative metrics, such as confidence intervals, are limited due to the ordinal nature of the data. Paired Subrank diagrams ameliorate this problem by providing a visualization of likelihood/uncertainty results and a useful risk assessment conceptual context. The numerical I-Rank points data can be analyzed using statistical methods appropriate for ordinal data. Results from my summary statistics indicate that the I-Rank

results are highly sensitive to weight factors assigned to each Subrank. Additional quantitative research to analyze effects of uncertainty, scale, and scoring modifications could yield useful information to improve future I-Rank studies.

Ecological Niche Models (ENM) could reduce I-Rank uncertainty and be useful in interpreting I-Rank results. Based on my feasibility study for ENM, I made several conclusions. A straightforward method of mapping model predictions should be identified early in the process to allow for visualization of responses to model modifications. Software selection is a crucial element of the research and the program should allow for automated simulations with ranges of parameter values. Sufficient occurrence data is often difficult to obtain and availability should be evaluated prior to undertaking ENM. Various aspects of model parameterization, including methods of generating absence data, have potential to greatly influence model predictions and should be thoroughly investigated.

The Nebraska I-Rank identified 10 species, which are noxious in neighboring states, that are unlikely to become invasive in Nebraska. Supporting data suggests that the assessment is performing well in classifying these species. The I-Rank study identified numerous potentially invasive plant species in Nebraska, including seven species not currently on the Nebraska Noxious Weed List or Nebraska Invasive Watch List. These species should be considered for listing on the Nebraska Invasive Watch List. All species that are currently on the Noxious List and NIS Watch List scored at least a Medium for Overall I-Rank upper estimate.

I-Rank results for several species resulted in high levels of overall uncertainty. For some species, these results can be interpreted post-hoc by evaluating sources of uncertainty and effects of scale, thus lessening uncertainty for management decisions. Other species will require additional research to reduce uncertainty and make conclusions feasible. For example, survey results indicate that plumeless thistle (*Carduus acanthoides* L.; I-Rank= INSIG-HIGH; Appendix D-10) is regarded as a low threat, despite being listed as a noxious weed in Nebraska. Additional state-level information should be researched to reduce uncertainty and determine whether plumeless thistle should be considered for removal from the Noxious List.

The utility of the I-Rank assessment is its ability to inform policy makers, land managers, and the public about invasive species. While other methods provide a better framework for quantitative analysis and significance testing, I-Rank results can be visualized and explained in a way that is intuitive and informative for scientists and non-scientists alike. The I-Rank assessment allows integration of data from multiple sources/scales based on the research needs and data availability, and it allows for incorporation of uncertainty. By gathering, synthesizing, and analyzing pertinent information, the I-Rank assessment can be used to evaluate, describe, prioritize, and inform about the risks of potentially harmful species.

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9. TABLES

Table 1- Nebraska Noxious Weed List- These plants are designated as “a serious threat to the economic, social, or aesthetic well-being of the residents of the state,” (NDA 2008).

Common Name	Scientific Name	Native Range
plumeless thistle	<i>Carduus acanthoides</i> L.	Eurasia
musk thistle	<i>Carduus nutans</i> L.	Eurasia
diffuse knapweed	<i>Centaurea diffusa</i> Lam.	Eurasia
spotted knapweed	<i>Centaurea stoebe</i> L.	Europe
Canada thistle	<i>Cirsium arvense</i> (L.) Scop.	Eurasia
leafy spurge	<i>Euphorbia esula</i> L.	Eurasia
purple loosestrife	<i>Lythrum salicaria</i> L.	Eurasia, Africa
common reed	<i>Phragmites australis</i> (Cav.) Trin. ex Steud.	Worldwide
saltcedar	<i>Tamarix ramosissima</i> Ledeb.	Eurasia

Table 2- Nebraska Invasive Species Watch List- These species are designated as being “potentially harmful invasive plants that need monitoring,”(NWCA 2008).

Common Name	Scientific Name	Native Range
garlic mustard	<i>Alliaria petiolata</i> (Bieb.) Cavara & Grande	Europe
Caucasian bluestem	<i>Bothriochloa bladhii</i> (Retz.) S.T. Blake	Eurasia
trailing crownvetch	<i>Coronilla varia</i> L.	Eurasia, Africa
houndstongue	<i>Cynoglossum officinale</i> L.	Eurasia
Russian-olive	<i>Elaeagnus angustifolia</i> L.	Eurasia
autumn-olive	<i>Elaeagnus umbellata</i> Thunb.	Eurasia
damesrocket	<i>Hesperis matronalis</i> L.	Europe
whitetop (three species)	<i>Cardaria</i> sp.	Eurasia
sericea lespedeza	<i>Lespedeza cuneata</i> (Dumont) G. Don	Asia
Dalmation toadflax	<i>Linaria dalmatica</i> (L.) Mill.	Mediterranean
yellow toadflax	<i>Linaria vulgaris</i> P. Mill.	Eurasia
Amur honeysuckle	<i>Lonicera maackii</i> (Rupr.) Herder	Asia
Scotch cottonthistle	<i>Onopordum acanthium</i> L.	Europe
European buckthorn	<i>Rhamnus cathartica</i> L.	Europe
multiflora rose	<i>Rosa multiflora</i> Thunb. ex Murr.	Asia

Table 3- Desirable Attributes of Invasive Species Risk Assessments- These attributes were ascertained through literature review (NRC 2002; Hiebert and Stubbendieck 1993; Landis 2004) and discussions with stakeholders.

-
- Provides a clear explanation of the process used to evaluate and categorize invasive species (i.e. transparent)
 - Provides a uniform methodology for categorizing invasive species using a logical framework that includes independent factors important in the invasion process
 - The assessment is repeatable, unbiased, and has been peer-reviewed
 - Incorporates uncertainty in predictions where knowledge gaps exist
 - The assessment method lends well to analytic process of indentifying, categorizing, prioritizing, non-native species with negative impacts to biodiversity
 - The method is flexible, so the criteria used can be adapted to meet specific research needs
 - The data required to use the method is available or can be readily obtained through research making the method feasible
 - Results from the assessment can inform policy makers, land managers, and the public about the biology, ecological impacts, and distribution of invasive species
-

Table 4- Non-Native Plant Species Evaluated- These species were evaluated with the I-Rank assessment. Additional information for each species can be found in Appendix D (page # listed below).

Common Name	Scientific Name	Family	Page # (App. D)
velvetleaf	<i>Abutilon theophrasti</i> Medik.	Malvaceae	2
Russian knapweed	<i>Acroptilon repens</i> (L.) DC.	Asteraceae	3
garlic mustard	<i>Alliaria petiolata</i> (Bieb.) Cavara & Grande	Brassicaceae	4
corn chamomile	<i>Anthemis arvensis</i> L.	Asteraceae	5
mayweed chamomile	<i>Anthemis cotula</i> L.	Asteraceae	6
common burdock	<i>Arctium minus</i> Bernh.	Asteraceae	7
absinth wormwood	<i>Artemisia absinthium</i> L.	Asteraceae	8
downy brome	<i>Bromus tectorum</i> L.	Poaceae	9
plumeless thistle	<i>Carduus acanthoides</i> L.	Asteraceae	10
musk thistle	<i>Carduus nutans</i> L.	Asteraceae	11
diffuse knapweed	<i>Centaurea diffusa</i> Lam.	Asteraceae	12
yellow starthistle	<i>Centaurea solstitialis</i> L.	Asteraceae	13
spotted knapweed	<i>Centaurea stoebe</i> L.	Asteraceae	14
chicory	<i>Cichorium intybus</i> L.	Asteraceae	15
Canada thistle	<i>Cirsium arvense</i> (L.) Scop.	Asteraceae	16
bull thistle	<i>Cirsium vulgare</i> (Savi) Ten.	Asteraceae	17
chicory	<i>Conium maculatum</i> L.	Apiaceae	18
field bindweed	<i>Convolvulus arvensis</i> L.	Convolvulaceae	19
chicory	<i>Cynoglossum officinale</i> L.	Boraginaceae	20
wild carrot	<i>Daucus carota</i> L.	Apiaceae	21
common teasel	<i>Dipsacus fullonum</i> L.	Dipsacaceae	22
cutleaf teasel	<i>Dipsacus laciniatus</i> L.	Dipsacaceae	23
Russian-olive	<i>Elaeagnus angustifolia</i> L.	Elaeagnaceae	24
autumn-olive	<i>Elaeagnus umbellata</i> Thunb.	Elaeagnaceae	25
quackgrass	<i>Elymus repens</i> (L.) Gould	Poaceae	26
redstem filaree	<i>Erodium cicutarium</i> (L.) L'Hér. ex Ait.	Geraniaceae	27
cypress spurge	<i>Euphorbia cyparissias</i> L.	Euphorbiaceae	28
leafy spurge	<i>Euphorbia esula</i> L.	Euphorbiaceae	29
halogeton	<i>Halogeton glomeratus</i>	Chenopodiaceae	30
damesrocket	<i>Hesperis matronalis</i> L.	Brassicaceae	31
Venice mallow	<i>Hibiscus trionum</i> L.	Malvaceae	32
black henbane	<i>Hyoscyamus niger</i> L.	Solanaceae	33

Table 4- (continued)

Common Name	Scientific Name	Family	Page # (App. D)
common St. Johnswort	<i>Hypericum perforatum</i> L.	Clusiaceae	34
perennial pepperweed	<i>Lepidium latifolium</i> L.	Brassicaceae	35
sericea lespedeza	<i>Lespedeza cuneata</i> (Dumont) G. Don	Fabaceae	36
oxeye daisy	<i>Leucanthemum vulgare</i> Lam.	Asteraceae	37
yellow toadflax	<i>Linaria vulgaris</i> P. Mill.	Scrophulariaceae	38
Amur honeysuckle	<i>Lonicera maackii</i> (Rupr.) Herder	Caprifoliaceae	39
narrow-leaf bird's-foot trefoil	<i>Lotus glaber</i> Mill.	Fabaceae	40
purple loosestrife	<i>Lythrum salicaria</i> L.	Lythraceae	41
Eurasian watermilfoil	<i>Myriophyllum spicatum</i> L.	Haloragaceae	42
common reed	<i>Phragmites australis</i> (Cav.) Trin. ex Steud.	Poaceae	43
buckhorn plantain	<i>Plantago lanceolata</i> L.	Plantaginaceae	44
sulfur cinquefoil	<i>Potentilla recta</i> L.	Rosaceae	45
kudzu	<i>Pueraria montana</i> var. <i>lobata</i> (Willd.) Maesen & S.M. Almeida	Fabaceae	46
European buckthorn	<i>Rhamnus cathartica</i> L.	Rhamnaceae	47
multiflora rose	<i>Rosa multiflora</i> Thunb. ex Murr.	Rosaceae	48
red sorrel	<i>Rumex acetosella</i> L.	Polygonaceae	49
bouncingbet	<i>Saponaria officinalis</i> L.	Caryophyllaceae	50
trailing crownvetch	<i>Coronilla varia</i> L.	Fabaceae	51
wild mustard	<i>Sinapis arvensis</i> L.	Brassicaceae	52
perennial sowthistle	<i>Sonchus arvensis</i> L.	Asteraceae	53
johnsongrass	<i>Sorghum halepense</i> (L.) Pers.	Poaceae	54
saltcedar	<i>Tamarix ramosissima</i> Ledeb.	Tamaricaceae	55
common tansy	<i>Tanacetum vulgare</i> L.	Asteraceae	56
common mullein	<i>Verbascum thapsus</i> L.	Scrophulariaceae	57

Table 5-Adapting I-Rank Methods for Application in Nebraska- These steps were used to modify the I-Rank for use in Nebraska, as suggested by Morse et al. (2004).

Steps to Adapt I-Rank method to a Specific Geographic Area	Nebraska I-Rank Modifications
1. Select and describe (or map) the exact geographical region of interest.	The geographic region of interest will be the entire state of Nebraska.
2. Select one or more sources for the taxonomic classification to be used for the species of interest in your region.	I used the USDA national PLANTS database (USDA 2008).
3. If the size or configuration of your region of interest is biogeographically unusual, make suitable adjustments (if needed) to the geographic distribution thresholds.	N/A
4. Select Biogeographic Units	I used EPA Level 3 Ecoregions for Nebraska (n=6; Chapman et al. 2001).
5. If there are very few biogeographic units for your region of interest, or if they are highly disproportionate in area, you may need to make systematic adjustments.	N/A
6. Select a specified set of habitats or ecological systems.	I used EPA Level 4 ecoregions (n=29; Chapman et al. 2001)

Table 6- Subrank Scoring System- The I-Rank assessment is comprised of 20 questions (see Appendix B), which are grouped into 4 sections called Subranks. The various questions in each Subrank are weighted differently to reflect their relative contributions. Answers for each question are assigned a point value, and summed point values are used to determine the Subrank class using the Subrank intervals shown below. Due to uncertainty in answering questions, a lower and upper estimate for each Subrank point total are separately tallied, which can result in a span of Subrank classes (e.g. Low to Moderate). All point values and intervals are taken from Morse et al. (2004).

Questions	High	Moderate	Low	Insignificant	Possible Points	Intervals	
I. Ecological Impacts						Subrank I	
1	33	22	11	0	0-33	78 - 102	High
2	18	12	6	0	0-18	52 - 77	Moderate
3	18	12	6	0	0-18	27 - 51	Low
4	9	6	3	0	0-9	0 - 26	Insignificant
5	24	16	8	0	0-24	Subrank II	
II. Current Distribution and Abundance						28 - 36	High
6	15	10	5	0	0-15	19 - 27	Moderate
7	15	10	5	0	0-15	10-18	Low
8	3	2	1	0	0-3	0 - 9	Insignificant
9	3	2	1	0	0-3	Subrank III	
III. Trend in Distribution and Abundance						55 - 72	High
10	18	12	6	0	0-18	37 - 54	Moderate
11	3	2	1	0	0-3	19 - 36	Low
12	9	6	3	0	0-9	0 - 18	Insignificant
13	18	12	6	0	0-18	Subrank IV	
14	6	4	2	0	0-6	39 -51	High
15	9	6	3	0	0-9	27 - 38	Moderate
16	9	6	3	0	0-9	14 - 26	Low
IV. Management Difficulty						0 - 13	Insignificant
17	18	12	6	0	0-18		
18	15	10	5	0	0-15		
19	15	10	5	0	0-15		
20	3	2	1	0	0-3		

Table 7- I-Rank Scoring System - The classes for each Subrank are scored according to the points system below, then summed to determine the overall I-Rank. Inherent in this I-Rank scoring system, are the relative weight factors which are designed to reflect relative contributions of each Subrank in determining the overall risk of impact on biodiversity. Due to uncertainty in determining the Subrank classes, lower and upper estimates for the I-Rank point total are separately tallied, which can result in a span of I-Rank classes (e.g. Moderate to High). All point values and intervals are taken from Morse et al. (2004).

Subranks	High	Moderate	Low	Insignificant	Possible Points	Relative Weight Factor	I-Rank Intervals	I-Rank Class
I. Ecological Impact	50	33	17	0	0 - 50	0.5	76 - 100	High
II. Current Distribution and Abundance	25	17	8	0	0 - 25	0.25	51 - 75	Moderate
III. Trend in Distribution and Abundance	15	10	5	0	0 - 15	0.15	26 - 50	Low
IV. Management Difficulty	10	7	3	0	0 - 10	0.1	0 - 25	Insignificant

Table 8- Primary Data Sources for I-Rank Species Evaluations- The table below lists primary data sources and how the information was used to complete species evaluations for the Nebraska I-Rank Assessment.

Data Source	Description	Data Utilized
Flora of Nebraska (Kaul et al. 2006)	keys, descriptions, and distribution maps of plant species in Nebraska	County level occurrences in Nebraska
Atlas of the Flora of the Great Plains (Barkley 1977)	Atlas companion to Flora of the Great Plains	County level occurrences beyond Nebraska
Natureserve Explorer Database (Natureserve 2008)	I-Rank assessment for Contiguous United States	Information from U.S. I-RANK to answer questions on ecological Impact, dispersal ability, reproductive ability, ability to invade mature vegetation, and management difficulty
Expert Opinion Surveys	Surveys completed by experts with knowledge of non-native plants in Nebraska	Answered questions about impacts, trend in total range, and local increases in range/abundance in Nebraska
USDA PLANTS Database (USDA 2013)	Comprehensive database providing standardized information about the plants of the U.S.	Taxonomic synonyms and county level records beyond Nebraska.
NE Weedmapper Points (NWCA 2008b)	georeferenced weed report locations from Nebraska Weed Control Association, includes only Noxious and NIS Watch List Species	Point occurrences used to answer distribution questions
NDA County Weed Reports (NDA 2008)	Number of acres infested in county weed reports, includes only Noxious and Watchlist Species	Mostly county level occurrences

Table 9 Expert Opinion and WMA Survey Respondents- Surveys responses were solicited from 13 state-wide experts and 13 Weed Management Areas (see Figure 1). A total of 16 completed surveys were received (62% response rate).

Expert Names	Title	Affiliation
Steve Rolfsmeier	Research Assistant, Herbarium	Kansas State University, Division of Biology
Robert Kaul	Curator	UNL, Bessey Herbarium
Jim Stubbendieck	Professor	UNL, Agronomy and Horticulture
Steven Knezevic	Integrated Weed Managment Specialist	UNL, Southeast Research & Extension Center
Gerry Steinaurer	Botanist	Nebraska Game and Parks Commission
Chris Helzer	Eastern Nebraska Program Director	The Nature Conservancy
Jerry Volesky	Extension Range and Forage Specialist	UNL, West Central Research & Extension Center
Bob Steinaurer	Botanist	unaffiliated

Weed Management Areas	Counties Included
PRIDE	Sioux, Dawes, Box Butte, Sheridan
Middle Niobrara	Cherry, Keya Paha, Brown, Rock
Northeast Nebraska	Boyd, Holt, Knox Antelope, Pierce, Wayne, Dixon, Cedar
West Central	Arthur, McPherson, Logan, Keith, Lincoln
Platte Valley	Dawson, Buffalo, Hall, Howard, Merrick, Polk, Hamilton, Gosper, Phelps, Kearney
Twin Valley	Furnas, Harlan, Franklin, Webster, Nuckolls, Thayer, Adams, Clay, Filmore
5 Rivers	Gage, Johnson, Nemaha, Pawnee, Richardson, Otoe, Cass
Lower Platte	York, Seward, Lancaster, Butler, Saunders, Douglas, Sarpy

Table 10- Nebraska I-Rank Assessment Results- This table lists the results from the Nebraska I-Rank Assessment for 56 non-native plant species. The 5 large columns represent results for overall I-Rank (left) and the 4 Subrank components . Within each large column, the smaller columns list lower and upper possibilities for each result, which sometimes span classes due to uncertainty. Possible classes, which indicate the level of risk for each result, are Insignificant (INSIG), Low significance (LOW), Moderate Significance (MED), and High Significance (HIGH). Colors were assigned to each risk class for purpose of clarity. Species are sorted by upper I-Rank class, then lower I-Rank class. See Table 4 For taxonomic authorities.

Common	Genus	species	I-RANK		Ecol. Impact		Current D&A		Trend D&A		Manage Diff.	
			lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
downy brome	<i>Bromus</i>	<i>tectorum</i>	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	MED	MED	MED	HIGH
purple loosestrife	<i>Lythrum</i>	<i>salicaria</i>	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
common reed	<i>Phragmites</i>	<i>australis</i>	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	MED	HIGH
saltcedar	<i>Tamarix</i>	<i>ramosissima</i>	HIGH	HIGH	HIGH	HIGH	MED	HIGH	MED	HIGH	MED	HIGH
Russian-olive	<i>Elaeagnus</i>	<i>angustifolia</i>	HIGH	HIGH	MED	HIGH	HIGH	HIGH	MED	MED	HIGH	HIGH
leafy spurge	<i>Euphorbia</i>	<i>esula</i>	HIGH	HIGH	MED	MED	HIGH	HIGH	MED	HIGH	HIGH	HIGH
perennial pepperweed	<i>Lepidium</i>	<i>latifolium</i>	MED	HIGH	HIGH	HIGH	INSIG	MED	LOW	HIGH	MED	HIGH
Eurasian watermilfoil	<i>Myriophyllum</i>	<i>spicatum</i>	MED	HIGH	HIGH	HIGH	INSIG	MED	LOW	MED	HIGH	HIGH
trailing crownvetch	<i>Coronilla</i>	<i>varia</i>	MED	HIGH	HIGH	HIGH	MED	HIGH	LOW	MED	LOW	LOW
autumn-olive	<i>Elaeagnus</i>	<i>umbellata</i>	MED	HIGH	HIGH	HIGH	LOW	HIGH	MED	HIGH	LOW	LOW
garlic mustard	<i>Alliaria</i>	<i>petiolata</i>	MED	HIGH	LOW	MED	HIGH	HIGH	MED	HIGH	MED	MED
common St. Johnswort	<i>Hypericum</i>	<i>perforatum</i>	MED	HIGH	LOW	MED	MED	HIGH	MED	HIGH	MED	MED
diffuse knapweed	<i>Centaurea</i>	<i>diffusa</i>	MED	HIGH	MED	HIGH	MED	MED	LOW	HIGH	MED	HIGH
Amur honeysuckle	<i>Lonicera</i>	<i>maackii</i>	MED	HIGH	MED	HIGH	LOW	HIGH	MED	HIGH	MED	MED
European buckthorn	<i>Rhamnus</i>	<i>cathartica</i>	MED	HIGH	MED	MED	MED	HIGH	MED	HIGH	MED	MED
musk thistle	<i>Carduus</i>	<i>nutans</i>	LOW	HIGH	INSIG	MED	HIGH	HIGH	MED	MED	MED	HIGH
buckhorn plantain	<i>Plantago</i>	<i>lanceolata</i>	LOW	HIGH	LOW	HIGH	LOW	MED	LOW	MED	LOW	HIGH
sulfur cinquefoil	<i>Potentilla</i>	<i>recta</i>	LOW	HIGH	LOW	HIGH	LOW	MED	LOW	MED	LOW	MED
quackgrass	<i>Elymus</i>	<i>repens</i>	LOW	HIGH	LOW	MED	MED	HIGH	LOW	HIGH	MED	HIGH

Table 10 (Continued)

Common	Genus	species	I-RANK		Ecol. Impact		Current D&A		Trend D&A		Manage Diff.	
			lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
yellow starthistle	<i>Centaurea</i>	<i>solstitialis</i>	LOW	HIGH	MED	HIGH	INSIG	LOW	LOW	MED	MED	HIGH
plumeless thistle	<i>Carduus</i>	<i>acanthoides</i>	INSIG	HIGH	INSIG	MED	MED	HIGH	LOW	MED	INSIG	HIGH
Canada thistle	<i>Cirsium</i>	<i>arvense</i>	MED	MED	LOW	LOW	HIGH	HIGH	MED	MED	MED	HIGH
spotted knapweed	<i>Centaurea</i>	<i>stoebe</i>	MED	MED	MED	MED	LOW	MED	MED	HIGH	LOW	HIGH
field bindweed	<i>Convolvulus</i>	<i>arvensis</i>	LOW	MED	INSIG	LOW	MED	HIGH	MED	MED	MED	HIGH
red sorrel	<i>Rumex</i>	<i>acetosella</i>	LOW	MED	INSIG	LOW	LOW	MED	MED	MED	HIGH	HIGH
poison-hemlock	<i>Conium</i>	<i>maculatum</i>	LOW	MED	LOW	LOW	MED	HIGH	LOW	MED	INSIG	LOW
multiflora rose	<i>Rosa</i>	<i>multiflora</i>	LOW	MED	LOW	LOW	MED	HIGH	LOW	MED	LOW	LOW
Russian knapweed	<i>Acroptilon</i>	<i>repens</i>	LOW	MED	LOW	MED	INSIG	MED	MED	MED	MED	HIGH
bull thistle	<i>Cirsium</i>	<i>vulgare</i>	LOW	MED	LOW	MED	MED	MED	LOW	MED	LOW	MED
cypress spurge	<i>Euphorbia</i>	<i>cyparissias</i>	LOW	MED	LOW	MED	INSIG	LOW	LOW	MED	MED	HIGH
sericea lespedeza	<i>Lespedeza</i>	<i>cuneata</i>	LOW	MED	LOW	MED	LOW	MED	MED	HIGH	LOW	MED
yellow toadflax	<i>Linaria</i>	<i>vulgaris</i>	LOW	MED	LOW	MED	LOW	MED	LOW	LOW	MED	HIGH
narrow-leaf bird's-foot trefoil	<i>Lotus</i>	<i>glaber</i>	LOW	MED	LOW	MED	LOW	MED	LOW	LOW	LOW	MED
johnson grass	<i>Sorghum</i>	<i>halepense</i>	LOW	MED	LOW	MED	INSIG	MED	LOW	MED	MED	HIGH
common mullein	<i>Verbascum</i>	<i>thapsus</i>	LOW	MED	LOW	MED	LOW	MED	MED	MED	LOW	LOW
halogeton	<i>Halogeton</i>	<i>glomeratus</i>	LOW	MED	MED	MED	INSIG	LOW	MED	MED	MED	HIGH
velvetleaf	<i>Abutilon</i>	<i>theophrasti</i>	INSIG	MED	INSIG	LOW	LOW	MED	LOW	MED	LOW	HIGH
common burdock	<i>Arctium</i>	<i>minus</i>	INSIG	MED	INSIG	LOW	LOW	HIGH	LOW	MED	INSIG	MED
houndstongue	<i>Cynoglossum</i>	<i>officinale</i>	INSIG	MED	INSIG	LOW	LOW	HIGH	LOW	HIGH	LOW	MED
oxeye daisy	<i>Leucanthemum</i>	<i>vulgare</i>	INSIG	MED	INSIG	LOW	LOW	MED	LOW	HIGH	MED	HIGH
perennial sowthistle	<i>Sonchus</i>	<i>arvensis</i>	INSIG	MED	INSIG	LOW	LOW	MED	LOW	MED	LOW	HIGH
mayweed chamomile	<i>Anthemis</i>	<i>cotula</i>	INSIG	MED	INSIG	MED	INSIG	LOW	INSIG	LOW	INSIG	HIGH
damesrocket	<i>Hesperis</i>	<i>matronalis</i>	INSIG	MED	INSIG	MED	MED	HIGH	LOW	MED	LOW	LOW

Table 10 (Continued)

Common	Genus	species	I-RANK		Ecol. Impact		Current D&A		Trend D&A		Manage Diff.	
			lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
Venice mallow	<i>Hibiscus</i>	<i>trionum</i>	INSIG	MED	INSIG	MED	INSIG	LOW	LOW	MED	INSIG	MED
black henbane	<i>Hyoscyamus</i>	<i>niger</i>	INSIG	MED	INSIG	MED	INSIG	LOW	LOW	LOW	INSIG	MED
redstem filaree	<i>Erodium</i>	<i>cicutarium</i>	INSIG	MED	LOW	MED	INSIG	LOW	LOW	MED	LOW	MED
common teasel	<i>Dipsacus</i>	<i>fullonum</i>	LOW	LOW	LOW	LOW	INSIG	LOW	MED	MED	LOW	MED
kudzu	<i>Pueraria</i>	<i>montana</i>	LOW	LOW	MED	MED	INSIG	INSIG	LOW	LOW	LOW	MED
bouncingbet	<i>Saponaria</i>	<i>officinalis</i>	INSIG	LOW	INSIG	INSIG	LOW	MED	INSIG	LOW	INSIG	HIGH
chicory	<i>Cichorium</i>	<i>intybus</i>	INSIG	LOW	INSIG	LOW	INSIG	MED	LOW	LOW	LOW	HIGH
cutleaf teasel	<i>Dipsacus</i>	<i>laciniatus</i>	INSIG	LOW	LOW	LOW	INSIG	LOW	LOW	MED	LOW	MED
corn chamomile	<i>Anthemis</i>	<i>arvensis</i>	INSIG	INSIG	INSIG	INSIG	INSIG	INSIG	INSIG	LOW	INSIG	HIGH
absinth wormwood	<i>Artemisia</i>	<i>absinthium</i>	INSIG	INSIG	INSIG	INSIG	INSIG	LOW	LOW	MED	INSIG	LOW
wild mustard	<i>Sinapis</i>	<i>arvensis</i>	INSIG	INSIG	INSIG	INSIG	LOW	LOW	LOW	LOW	LOW	MED
wild carrot	<i>Daucus</i>	<i>carota</i>	INSIG	INSIG	INSIG	INSIG	INSIG	LOW	LOW	LOW	INSIG	INSIG
common tansy	<i>Tanacetum</i>	<i>vulgare</i>	INSIG	INSIG	INSIG	INSIG	INSIG	LOW	INSIG	LOW	MED	MED

Table 11- Nebraska I-Rank Results for Noxious and NIS Watch Lists- This table lists the results from the Nebraska I-Rank Assessment for species listed on the Nebraska Noxious Weed List (NDA 2008) and the Nebraska Invasive Species (NIS) Watch List (NWCA 2008a). The 5 large columns represent results for overall I-Rank (left) and the 4 Subrank components (Ecological Impacts, Current Distribution and Abundance, Trends in Distribution and Abundance, and Management Difficulty). Within each large column, the smaller columns list lower and upper possibilities for each result, which sometimes span classes due to uncertainty. Possible classes, which indicate the level of risk for each result, are Insignificant (INSIG), Low significance (LOW), Moderate Significance (MED), and High Significance (HIGH). Colors were assigned to each risk class for purpose of clarity.

Common Name	Genus	Species	I-RANK		Ecol. Impact		Current D&A		Trend D&A		Manage Diff.	
			lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
garlic mustard	<i>Alliaria</i>	<i>petiolata</i>	MED	HIGH	LOW	MED	HIGH	HIGH	MED	HIGH	MED	MED
plumeless thistle	<i>Carduus</i>	<i>acanthoides</i>	INSIG	HIGH	INSIG	MED	MED	HIGH	LOW	MED	INSIG	HIGH
musk thistle	<i>Carduus</i>	<i>nutans</i>	LOW	HIGH	INSIG	MED	HIGH	HIGH	MED	MED	MED	HIGH
diffuse knapweed	<i>Centaurea</i>	<i>diffusa</i>	MED	HIGH	MED	HIGH	MED	MED	LOW	HIGH	MED	HIGH
spotted knapweed	<i>Centaurea</i>	<i>stoebe</i>	MED	MED	MED	MED	LOW	MED	MED	HIGH	LOW	HIGH
Canada thistle	<i>Cirsium</i>	<i>arvense</i>	MED	MED	LOW	LOW	HIGH	HIGH	MED	MED	MED	HIGH
trailing crownvetch	<i>Coronilla</i>	<i>varia</i>	MED	HIGH	HIGH	HIGH	MED	HIGH	LOW	MED	LOW	LOW
houndstongue	<i>Cynoglossum</i>	<i>officinale</i>	INSIG	MED	INSIG	LOW	LOW	HIGH	LOW	HIGH	LOW	MED
Russian-olive	<i>Elaeagnus</i>	<i>angustifolia</i>	HIGH	HIGH	MED	HIGH	HIGH	HIGH	MED	MED	HIGH	HIGH
autumn-olive	<i>Elaeagnus</i>	<i>umbellata</i>	MED	HIGH	HIGH	HIGH	LOW	HIGH	MED	HIGH	LOW	LOW
leafy spurge	<i>Euphorbia</i>	<i>esula</i>	HIGH	HIGH	MED	MED	HIGH	HIGH	MED	HIGH	HIGH	HIGH
damesrocket	<i>Hesperis</i>	<i>matronalis</i>	INSIG	MED	INSIG	MED	MED	HIGH	LOW	MED	LOW	LOW
common St. Johnswort	<i>Hypericum</i>	<i>perforatum</i>	MED	HIGH	LOW	MED	MED	HIGH	MED	HIGH	MED	MED
sericea lespedeza	<i>Lespedeza</i>	<i>cuneata</i>	LOW	MED	LOW	MED	LOW	MED	MED	HIGH	LOW	MED
yellow toadflax	<i>Linaria</i>	<i>vulgaris</i>	LOW	MED	LOW	MED	LOW	MED	LOW	LOW	MED	HIGH
Amur honeysuckle	<i>Lonicera</i>	<i>maackii</i>	MED	HIGH	MED	HIGH	LOW	HIGH	MED	HIGH	MED	MED
purple loosestrife	<i>Lythrum</i>	<i>salicaria</i>	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
common reed	<i>Phragmites</i>	<i>australis</i>	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	MED	HIGH
European buckthorn	<i>Rhamnus</i>	<i>cathartica</i>	MED	HIGH	MED	MED	MED	HIGH	MED	HIGH	MED	MED
multiflora rose	<i>Rosa</i>	<i>multiflora</i>	LOW	MED	LOW	LOW	MED	HIGH	LOW	MED	LOW	LOW
saltcedar	<i>Tamarix</i>	<i>ramosissima</i>	HIGH	HIGH	HIGH	HIGH	MED	HIGH	MED	HIGH	MED	HIGH

Table 12- Statistics for Quantifying Uncertainty- This table list results for three statistics developed to quantify aspects of uncertainty in Nebraska I-Rank Assessment predictions. The statistics are Raw Average Variation (RAV), Proportionate Average Variation (PAV), and Proportion of I-Rank Uncertainty (PIU). Values used to calculate the statistics are also listed for Maximum Interval Range (MaxRange) and Subrank Weight Factor (W). Statistic equations are provided in Section 3E.

	I. Ecological Impact	II. Current Distrib/Abun.	III. Trend Distrib/Abun.	IV. Manage Difficulty
Raw Average Variation (RAV)	21.1	8.9	14.7	14.6
Proportionate Average Variation (PAV)	0.2	0.2	0.2	0.3
Proportion of I-Rank Uncertainty (PIU)	0.5	0.3	0.1	0.1
Maximum Point Range (MaxRange)	102.0	36.0	72.0	51.0
Subrank Weight Factor (W)	0.5	0.3	0.2	0.1

Table 13- Species Recommended for Further Consideration- These species have an upper I-Rank estimate of HIGH and are not listed on the Nebraska Noxious Weed List (Table 1) or Nebraska Invasive Species Watch List (Table 2). These species should be considered for listing on the Nebraska Invasive Species Watchlist, by interpreting the results from the Nebraska I-Rank Assessment. A summary for these species can be found in Appendix D (page number listed below). See Table 4 For taxonomic authorities.

Common	Genus	Species	I-Rank	App. D Page#
downy brome	<i>Bromus</i>	<i>tectorum</i>	HIGH	9
perennial pepperweed	<i>Lepidium</i>	<i>latifolium</i>	MED-HIGH	35
Eurasian watermilfoil	<i>Myriophyllum</i>	<i>spicatum</i>	MED-HIGH	42
sulfur cinquefoil	<i>Potentilla</i>	<i>recta</i>	LOW-HIGH	45
quackgrass	<i>Elymus</i>	<i>repens</i>	LOW-HIGH	26
yellow starthistle	<i>Centaurea</i>	<i>solstitialis</i>	LOW-HIGH	13
buckhorn plantain	<i>Plantago</i>	<i>lanceolata</i>	LOW-HIGH	44

Table 14- Environmental Data for Preliminary CART Models- This table lists the environmental data used for preliminary classification tree (CART) models. Pixel size (resolution) for the raster data varied from 0.5 kilometer (km) to 0.5 decimal degrees (dd). All Intergovernmental Panel on Climate Change (IPCC) data uses 30 year averages from 1961 to 1990 (IPCC 2001). University of Maryland (UM) data is a global estimate of percent tree cover (Hansen et al. 2003). International Soil Reference and Information Centre (ISRIC) data is ordinal classes (low, medium, high) of soil water capacity (Batjes 2005). U.S. Geological Survey (USGS) data is derived from digital elevation models (USGS 2001).

Variable	Resolution	Source
Slope	1 km	USGS
Elevation	1 km	USGS
Soil Water Capacity (classes)	0.5 dd	ISRIC
Percent Tree Cover	0.5 km	UM
Ground-frost Frequency	0.5 dd	IPCC
Precipitation	0.5 dd	IPCC
Radiation	0.5 dd	IPCC
Minimum Temperature	0.5 dd	IPCC
Mean Temperature	0.5 dd	IPCC
Maximum Temperature	0.5 dd	IPCC
Vapour Pressure	0.5 dd	IPCC
Wet Day Frequency	0.5 dd	IPCC
Diurnal Temperature Range	0.5 dd	IPCC

10. FIGURES

Figure 1– Nebraska Weed Management Areas- Nebraska has a statewide monitoring and control program administered through The Nebraska Weed Control Association (NWCA) and the Nebraska Department of Agriculture (NDA) Noxious Weeds Program, and is comprised of weed authorities in all 93 Nebraska Counties. Groups of counties are organized into Weed Management Areas (WMAs) that bring together landowners and managers (private, city, county, State, and Federal) in geographical areas to coordinate efforts and expertise for invasive weeds.

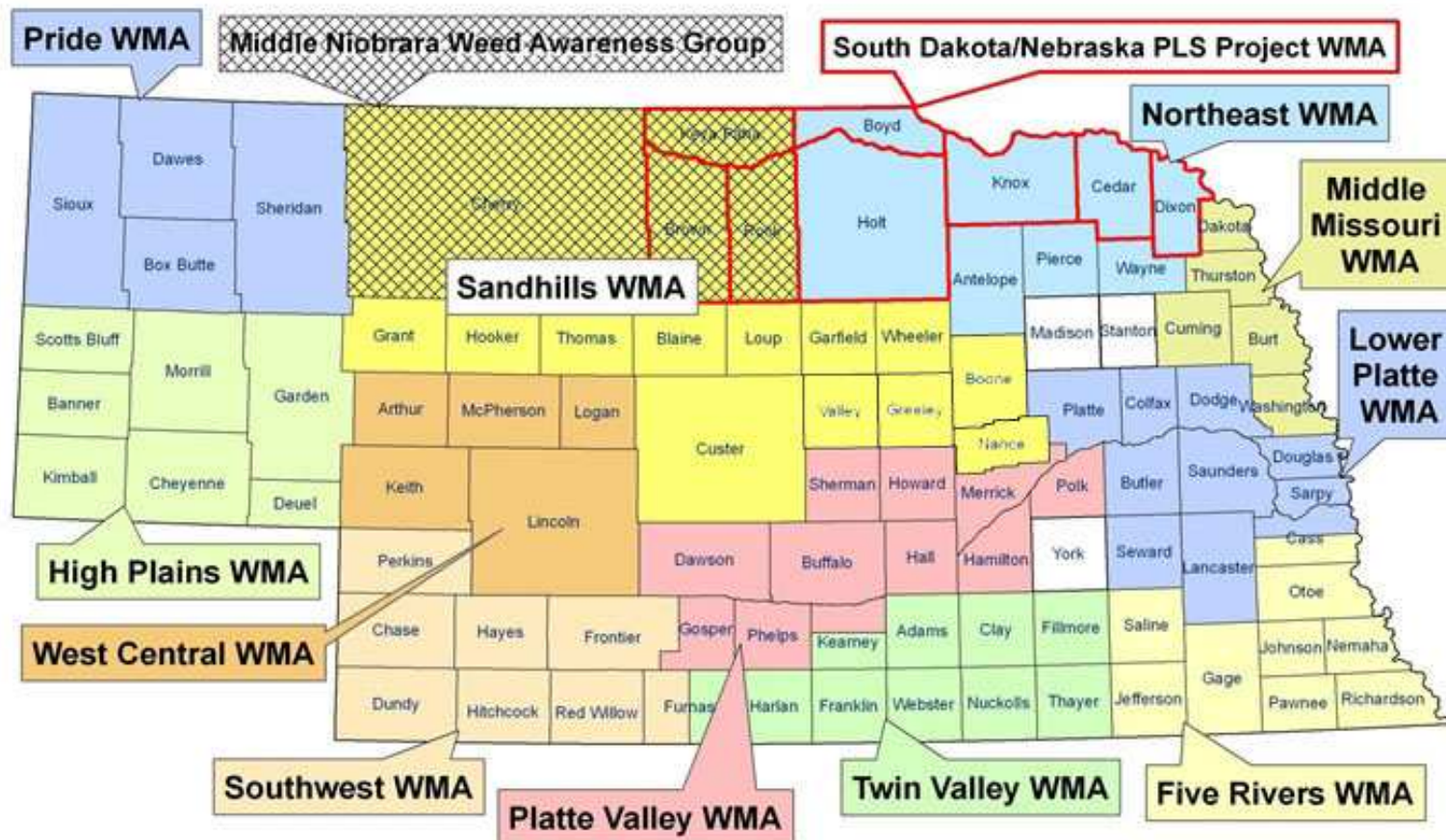


Figure 2- Traditional Risk Assessment Concept- Traditional Risk Assessments are comprised of five components: a stressor, exposure, receptor, effect, and a response. After defining the stressor, receptor, and response, one can quantify the likelihood of an event (exposure) and determining the associated consequences or impact (effect).

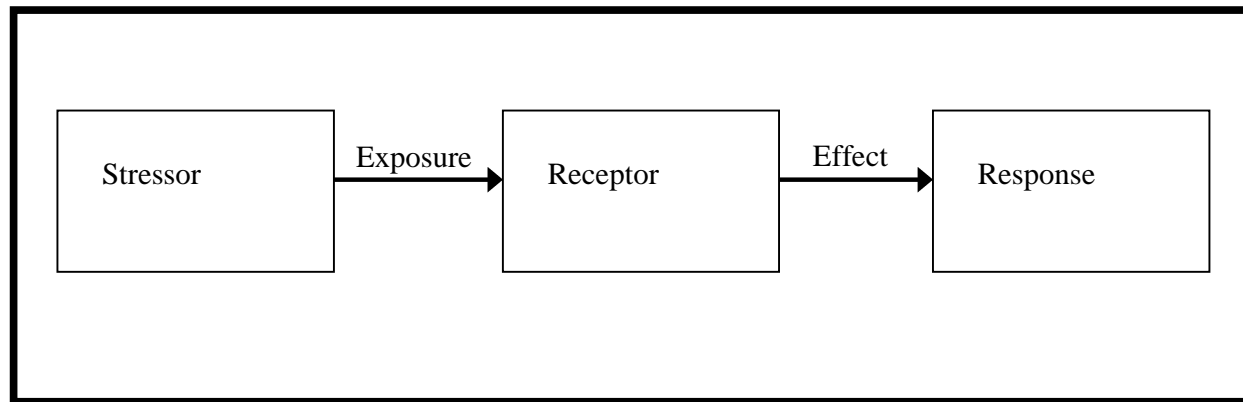


Figure 3- Risk Assessment Concept for Invasive Species- When applying the risk assessment concept to invasive species assessments, the risk assessment components must be re-defined. The stressors are non-native species, the exposure is chance of becoming established, the receptors are native species or ecosystems, the effect to be quantified is the potential for negative impacts (ecological/or economic), and the response is defined as the ecological consequences of invasion.

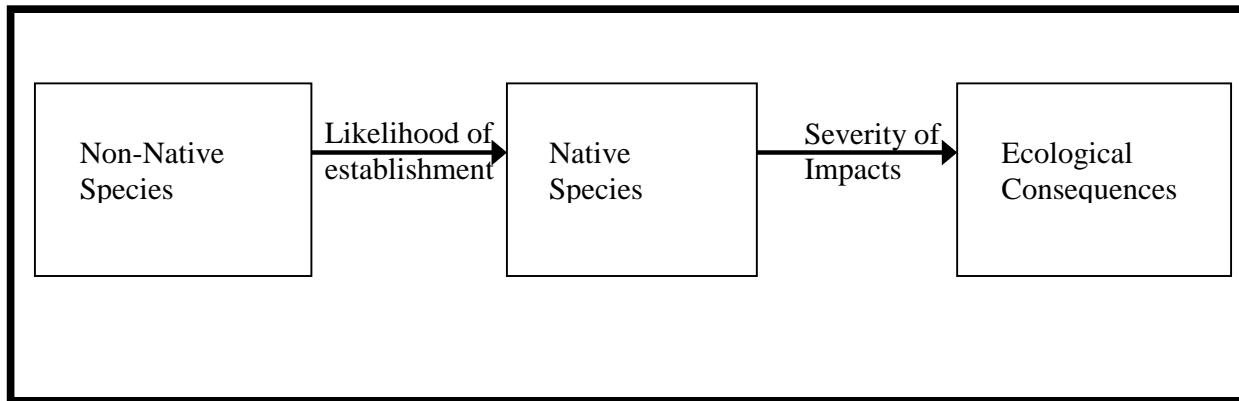


Figure 4- Conceptual Diagram of I-Rank Risk Assessment Method- The I-Rank assessment is comprised of 20 questions (shown on left), which are grouped into 4 sections called Subranks (I. Ecological Impacts, II. Current Distribution and Abundance, III. Trend in Distribution and Abundance, and IV. Management Difficulty). Answers to questions are assigned point totals, which are tallied to determine a risk class for each Subrank. The Subranks are similarly combined using scaled point values to calculate the overall I-Rank for each species.

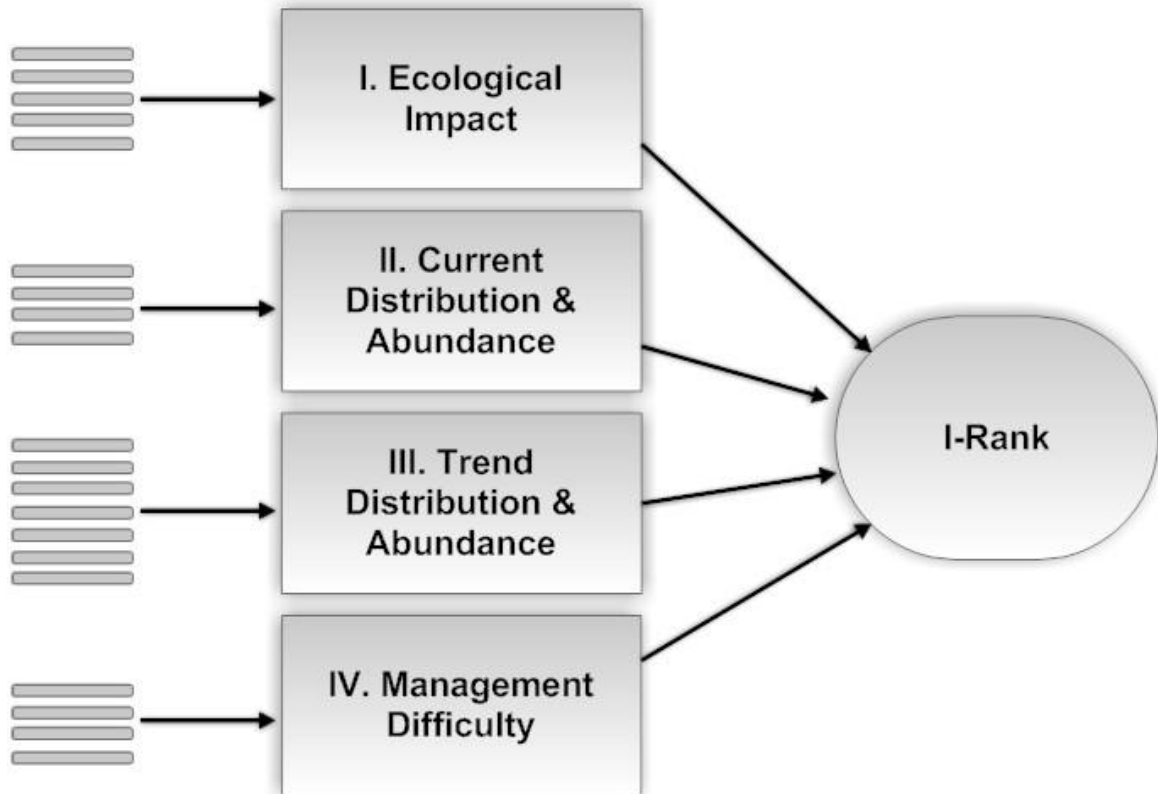


Figure 5- Level 3 Ecoregions of Nebraska - There are 6 EPA Level 3 Ecoregions in Nebraska (Chapman et al. 2001), which extend beyond Nebraska from Texas to the Canadian border.

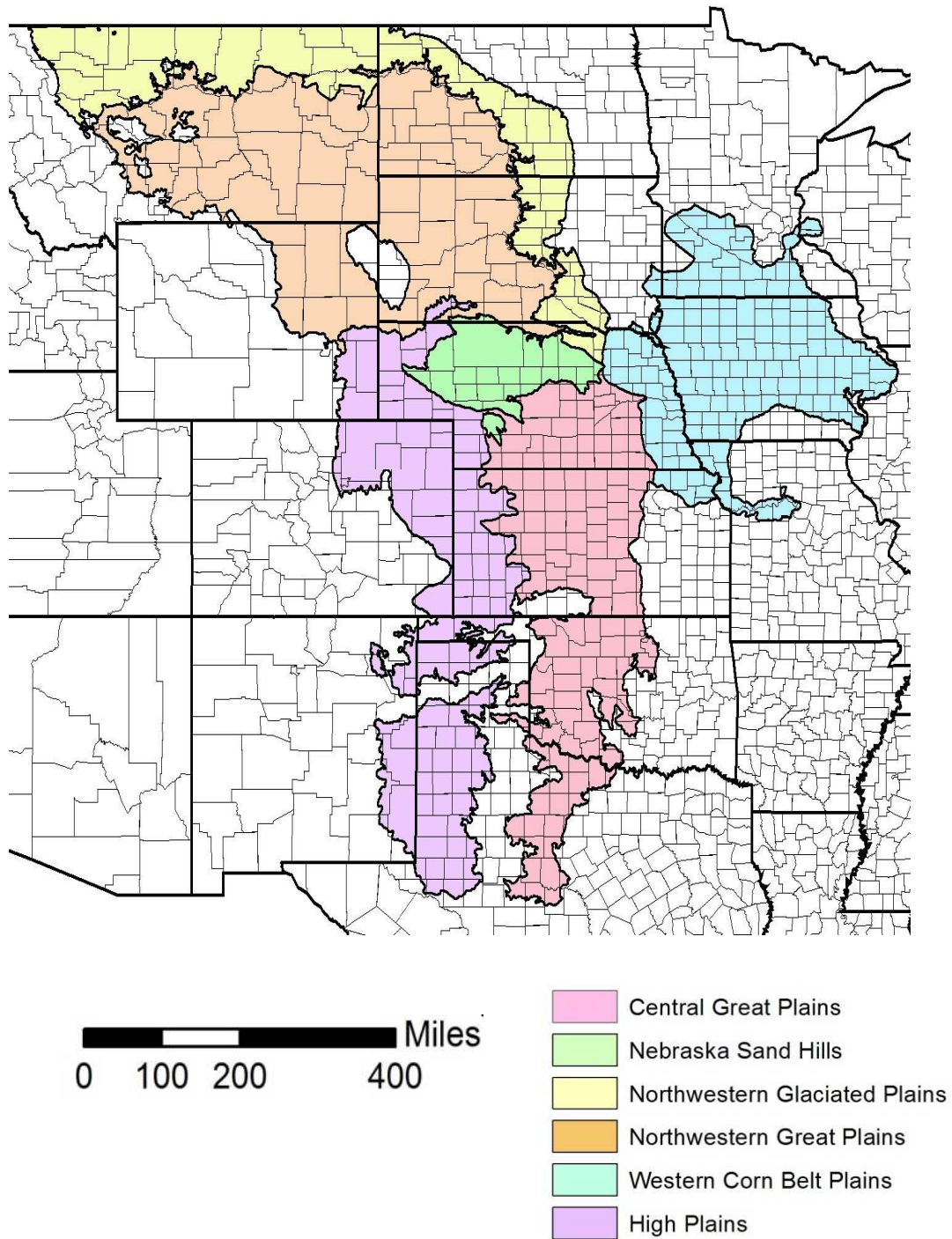
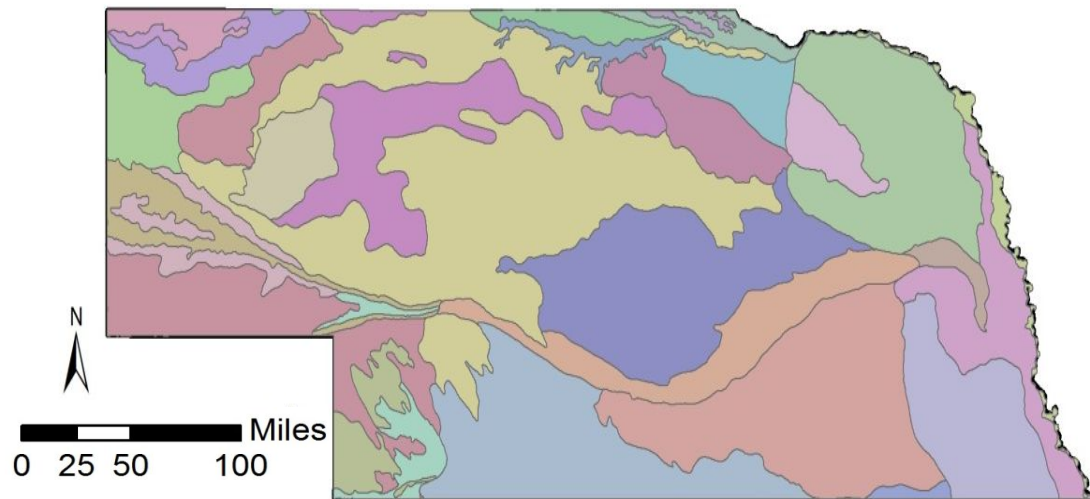


Figure 6- Level 4 Ecoregions of Nebraska. There are 29 different EPA Level 4 Ecoregions in Nebraska (Chapman et al. 2001).



Legend

Level 4 Ecoregions

Alkaline Lakes Area	Pine Ridge Escarpment
Central Nebraska Loess Plains	Platte River Valley
Flat to Rolling Plains	Platte River Valley and Terraces
Holt Tablelands	Ponca Plains
Keya Paha Tablelands	Rainwater Basin Plains
Lakes Area	Rolling Plains and Breaks
Loess and Glacial Drift Hills	Rolling Sand Plains
Lower Platte Alluvial Plain	Sand Hills
Missouri Alluvial Plain	Sandy and Silty Tablelands
Moderate Relief Plains	Semiarid Pierre Shale Plains
Nebraska/Kansas Loess Hills	Smoky Hills
Niobrara River Breaks	Southern River Breaks
Northeastern Nebraska Loess Hills	Transitional Sandy Plain
Pine Bluffs and Hills	Wet Meadow and Marsh Plain
	White River Badlands

Figure 7- Nebraska I-Rank Assessment Results by I-Rank Class- This histogram depicts frequencies of I-Rank classes predicted for 56 non-native plant species in Nebraska.

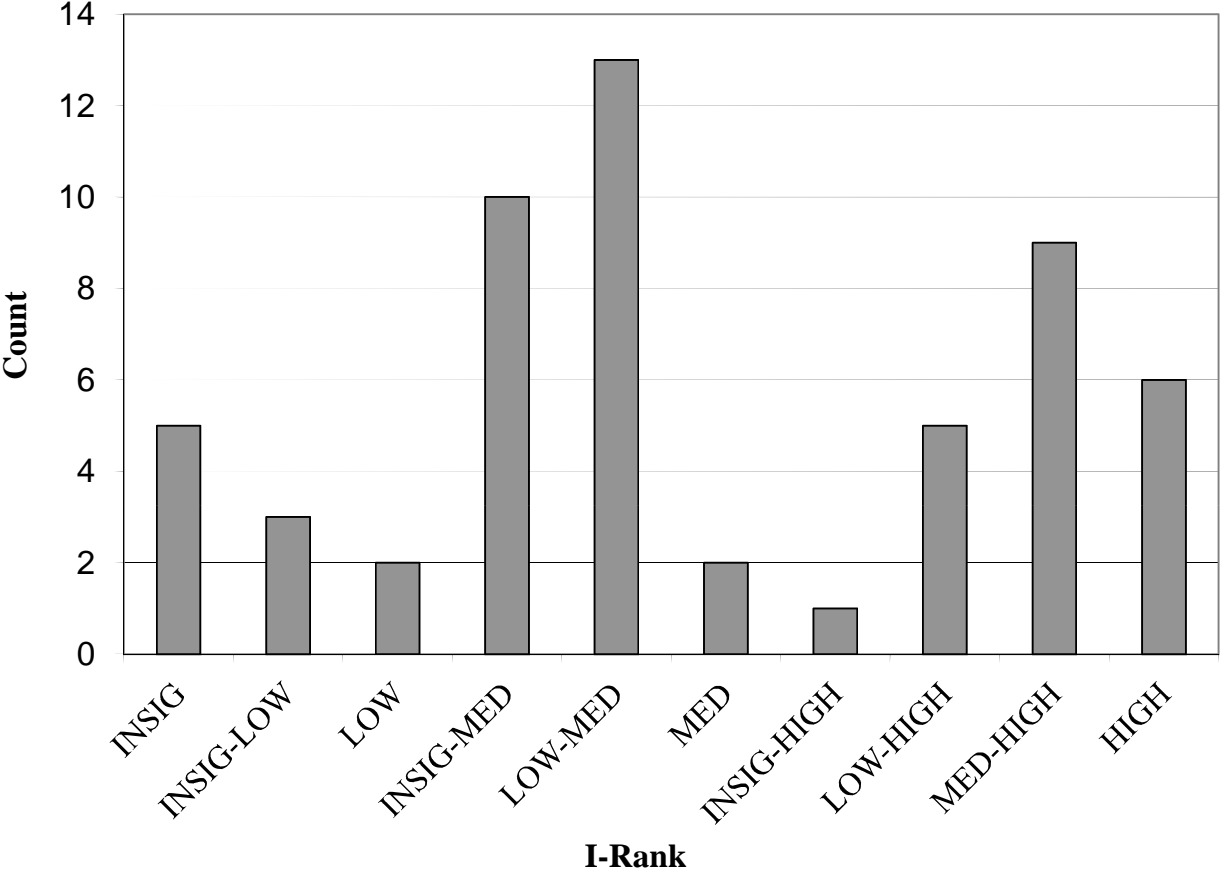


Figure 8- I Rank Results Scatterplot- This figure depicts I-Rank results for 56 non-native plant species in Nebraska. The x axis is lower estimate for I-Rank points, and the y axis is the upper I-Rank point estimate. The dashed horizontal and vertical lines represent cut points between I-Rank classes, which are labeled accordingly. The diagonal line represents zero uncertainty in I-Rank predictions. Some species had equal point values for both upper and lower point totals, and the overlapping points appear as a single point.

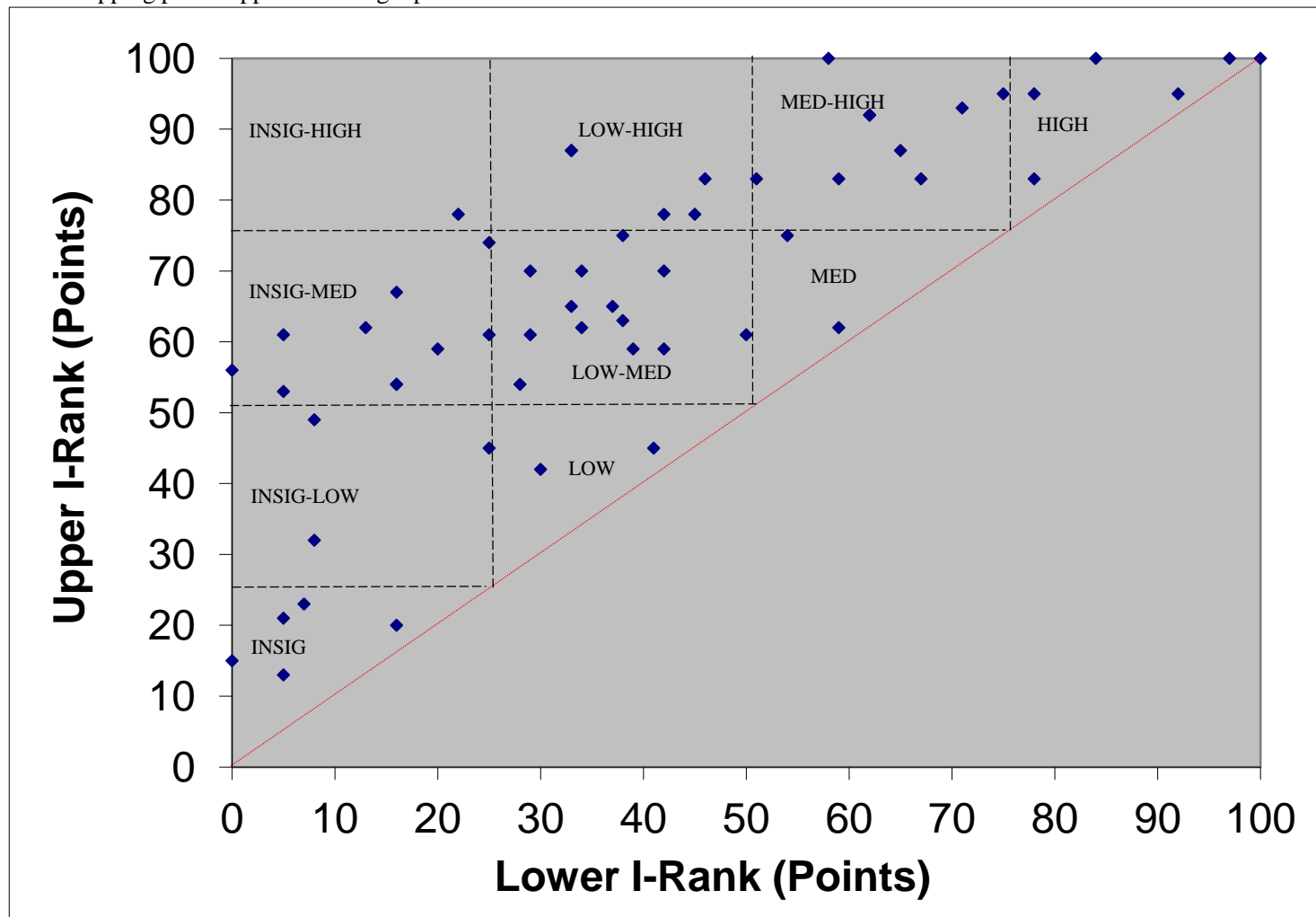


Figure 9- Conceptual Management Decision Framework- The I-Rank assessment can be used as part of analytic framework for management actions/decisions regarding non-native plant species. Data, theory, and models are used to document evidence for invasion likelihood and impact severity. Using a Risk Assessment method based on research needs, one can calculate risk and quantify uncertainty. Interpreting results can inform management decisions. Increased monitoring data can reduce uncertainty in future assessments.

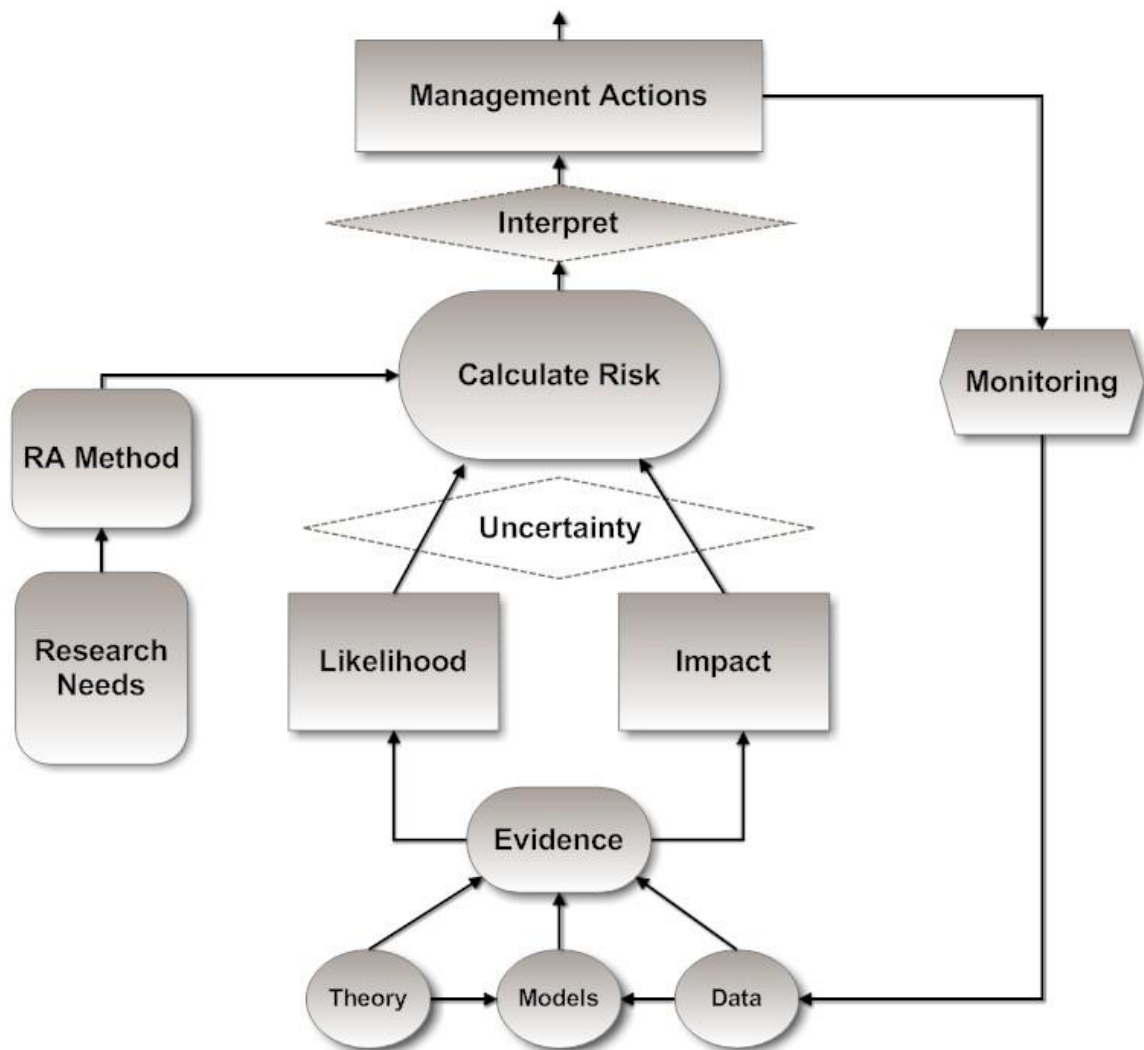
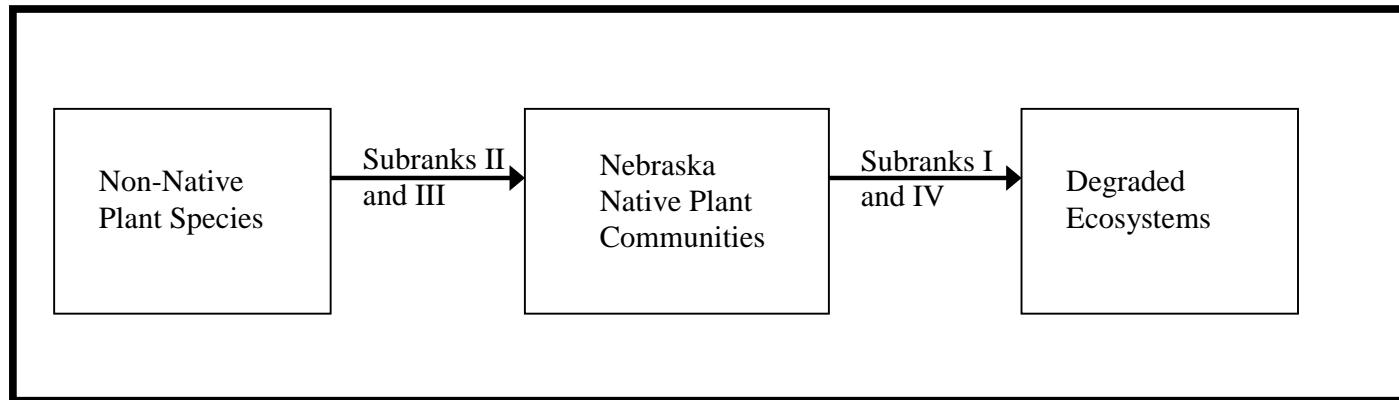


Figure 10- Risk Assessment Concept Applied to I-Rank Framework. Understanding the risk assessment context for the Nebraska I-Rank Assessment can enhance communication of results. In this framework, the stressors are non-native plant species, the exposure is quantifying potential contact with an invasive species (as summarized by Subranks II-Current Distribution/Abundance and Subrank III- Trend in Distribution/Abundance), the receptors are Nebraska native plant communities, the quantified effect is severity of impacts (as summarized by Subrank I-Ecological Impacts and Subrank IV-Management Difficulty), and the response is defined as degraded ecosystems.



11. APPENDICES

GUIDELINES AND CRITERIA
For
NEBRASKA WATCHLIST

Purpose of Watch List

1. To alert citizens about plants that have the potential to have a negative impact on the Nebraska economy and natural resources.
2. To prevent plant invasion and eradicate plants currently not listed as a noxious weed in Nebraska.

Organization(s) to Administer Watch List

1. Nebraska Department of Agriculture
2. Nebraska Weed Control Association

Criteria for Placing Plant on Watch List

1. The plant poses a threat to Nebraska's economy, environment, social welfare, wildlife, or safety.
2. The plant should not be native to Nebraska.
3. Potential exists for plant to invade Nebraska habitats.
4. The plant is listed as a noxious weed in one or more bordering states.
5. Nebraska Weed Control Association requests that a plant be listed.
6. Nebraska Noxious Weed Advisory Committee requests that a plant be listed.
7. Evidence that plant is invasive outside Nebraska.
8. Evidence that plant has had negative impact on economy and land resource outside Nebraska.
9. Plant has been documented to occur in Nebraska.

**Criteria 1,2,3, are mandatory and at least 3 of criteria 4,5,6,7,8, or 9 must apply before a plant is considered by NNWAC to be placed on the Watch List.*

Mechanisms of Information Dissemination

1. Watch List will be included in the Nebraska Department of Agriculture and Nebraska Weed Control Association websites.
2. Brochures (linkages with Nebraska Cooperative Extension Service).
 - a. Watch list concept;
 - b. Identification (with picture) and characteristics of watch list plant;
 - c. Plant control measures
3. Public meetings/Displays
4. NDA newsletter/news releases/NWCA Times
5. Linkages with other groups (Nebraska Section, Society for Range Management, Extension Service, University of Nebraska (School of Natural Resources), Game and Parks Commission, USDA-NRCS, USDA-ARS, USDA-APHIS, USDA-Forest Service, Nebraska Forest Service, USDI-Fish and Wildlife Service, USDI-National Park Service.
6. Annual rangeland, pasture, and non-cropland weed conference.
7. Methodology on how to identify or collect, preserve, and ship plants for proper identification.

Appendix B- I-Rank Questions Adapted for Nebraska

Questions and answers are adapted from Morse et al. (2004), using modifications for application in Nebraska.

Section I. Ecological Impact

(5 questions; 50% of I-Rank Score)

1. Impact on Ecosystem Processes and System-Wide Parameters (33 points)

A. High significance. Major, possibly irreversible, alteration or disruption of abiotic ecosystem processes and system-wide parameters, such as:

- The species promotes fire in habitats that otherwise rarely support fires;
- The species drains water from open water or wetland systems through rapid transpiration, making these unable to support native wetland plant and animal species; or
- The species is a nitrogen fixer and invades systems with few or no known native nitrogen fixers, and consequently causes soil nitrogen availability to increase to levels that favor other non-native invaders at the expense of native species

B. Moderate significance. Significant alteration in abiotic ecosystem processes and system-wide parameters (e.g., increases sedimentation rates along coastlines, reducing open water areas that are important for waterfowl)

C. Low significance. Influences abiotic ecosystem processes and system-wide parameters (e.g., has perceivable but mild influence on soil nutrient availability)

D. Insignificant. No perceivable impact on abiotic ecosystem processes and system-wide parameters

U. Unknown.

2. Impact on Ecological Community Structure (18 points)

A. High significance. Major alteration of ecological community structure (e.g., covers canopy or creates new canopy, changing or eliminating most or all layers of vegetation below)

B. Moderate significance. Changes number of layers below canopy, or significantly alters structure of at least one layer of the vegetation (e.g., creation of a new layer, elimination of an existing layer, substantial change in density or total cover of an existing layer)

C. Low significance. Influences structure of at least one layer (e.g., moderately changes density or total cover of a layer)

D. Insignificant. No impact; establishes within existing layers without influencing their structure

U. Unknown.

3. Impact on Ecological Community Composition (18 points)

A. High significance. Causes major alteration in ecological community composition. For example, results in:

- the extirpation or sharp reduction in abundance of several locally common native plant, animal, or fungal species (e.g., effects of increased shade, competition for water or nutrients, or allelopathy), or
- significant increases in the proportion of other non-native species in the community, or
- suppression of seedlings of native successional or climax species, leading to altered community composition over time

B. Moderate significance. Significantly alters ecological community composition (e.g., produces a significant reduction in the population size of one or more locally common native species in an ecological community)

C. Low significance. Influences ecological community composition (e.g., reduces recruitment of one or more locally common native species which will likely result in significant reduction in the long-term abundance of these species)

D. Insignificant. No impact; causes no perceivable change in locally common native species populations

U. Unknown.

4. Impact on Individual Native Plant or Animal Species (9 points)

A. High significance. Major impacts on particular native species (e.g., in places they co-occur, has negative impacts on more than 50% of the individuals of one or more native species)

B. Moderate significance. Significant impact on particular native species (e.g., has negative impacts on 20 to 50% of the individuals of one or more native species)

C. Low significance. Occasional impact on particular native species (e.g., has negative impacts on 5 to 20% of the individuals of one or more native species)

D. Insignificant. Little or no impact on particular native species (e.g., no known reports of competitive suppression, hybridization, parasitism, or other particular disproportionate negative impacts)

U. Unknown.

5. Conservation Significance of the Communities and Native Species Threatened (24 points)

A. High significance. For example, often threatens one or more rare or vulnerable native species or ecological communities, and/or high-quality occurrences of more common ecological communities

B. Moderate significance. For example, may occasionally threaten one or more rare or vulnerable native species or ecological communities, and/or high-quality occurrences of more common ecological communities

C. Low significance. For example, usually inhabits common, unthreatened habitats and rarely threatens rare or vulnerable native species or ecological communities, and/or high-quality occurrences of more common ecological communities

D. Insignificant. For example, found primarily or only in human-disturbed habitats and not known to threaten any rare or vulnerable native species or ecological communities, and/or any high-quality occurrences of more common ecological communities

U. Unknown.

Section II. Current Distribution And Abundance
(4 questions; 25% of I-Rank Score)

6. Current Range Size in Nebraska (15 points)

The range size considered here is the entire generalized range where the species is present within the region as a non-native outside cultivation, not just the range where it has its greatest impacts. The area of the generalized range is usually much greater than actual acreage infested.

A. High significance. Widespread in (e.g., >30% of Nebraska; >23,000 sq. mi.).

B. Moderate significance. Substantial part of Nebraska (e.g., 10-30% of Nebraska; 7,700 – 23,000 sq. mi.).

C. Low significance. Small part of Nebraska (e.g., 0.1-10% of Nebraska; 77 – 7,700 sq. mi.).

D. Insignificant. Isolated or spotty range in Nebraska (e.g., <0.1% of region; <77 sq. mi.).

U. Unknown.

7. Proportion of Current Range Where Species Is Negatively Impacting Biodiversity (15 points)

Within what proportion of the species' generalized range (from Question 6 above) is the species causing noticeable negative impacts on biodiversity?

A. High significance. Impacts occur in >50% of the species' current generalized range in the region of interest

B. Moderate significance. Impacts occur in 20 - 50% of the species' current generalized range

C. Low significance. Impacts occur in 5 - 20% of the species' current generalized range

D. Insignificant. Impacts occur in <5% of the species' current generalized range in region

U. Unknown.

8. Proportion of Biogeographic Units Invaded in Nebraska (3 points)

Biogeographic units are EPA Level 3 Ecoregions within Nebraska (n=6).

A. High significance. Present in 4+ biogeographic units.

B. Moderate significance. Present in 3 biogeographic units.

C. Low significance. Present in a 2 biogeographic units.

D. Insignificant. Present in only 1 biogeographic unit.

U. Unknown.

9. Diversity of Habitats or Ecological Systems Invaded in Region (3 points)

Ecological Systems are defined as EPA Level 4 Ecoregions within Nebraska (n=29).

- A. High significance.** Most (15+) ecological systems invaded.
- B. Moderate significance.** Many (6-14) ecological systems invaded
- C. Low significance.** Moderate number (2-5) of ecological systems invaded
- D. Insignificant.** Only a single ecological system invaded
- U. Unknown.**

Section III. Trend in Distribution and Abundance

(7 questions; 15% of I-Rank Score)

10. Current Trend in Total Range Within the Region (18 points)

- A. High significance.** Range expanding in most or all directions, and/or spreading into new portions of Nebraska.
- B. Moderate significance.** Range increasing in some directions but not most or all.
- C. Low significance.** Range stable, or areas of range contraction balancing areas of expansion.
- D. Insignificant.** Range decreasing.
- U. Unknown.**

11. Proportion of Potential Range Currently Occupied (3 points)

- A. High significance.** Less than 10% of potential range currently occupied
- B. Moderate significance.** 10-30% of potential range currently occupied
- C. Low significance.** 30-90% of potential range currently occupied
- D. Insignificant.** Greater than 90% of potential range currently occupied
- U. Unknown.**

12. Long-Distance Dispersal Potential Within Region (9 points)

- A. High significance.** Long-distance dispersal frequent (e.g., seed or other propagules frequently carried long distances by humans, wide-ranging birds or mammals, wind [especially spores or tiny seeds], or river currents; or plants commonly sold commercially and transported substantial distances)
- B. Moderate significance.** Long-distance dispersal infrequent (e.g., seeds carried occasionally by unusually strong winds, more localized birds or mammals, or periodic floods, or plants occasionally transported by human actions)
- C. Low significance.** Long-distance dispersal rare but known (e.g., major floods, hurricanes, or other unusual weather events)
- D. Insignificant.** Long-distance dispersal seldom or never
- U. Unknown.**

13. Local Range Expansion or Change in Abundance (18 points)

Is the species increasing in abundance (cover, density, frequency, etc.) within its current non-native range in the region and/or locally expanding within or at the edges of this range (peripheral expansion, generally <100 km or 60 miles), based on trends of the past 10-20 years?

A. High significance. Local range and/or species abundance increasing rapidly (e.g., area occupied likely to double within 10 years in most areas where it doesn't already fully occupy its potential habitat), and/or abundance increasing significantly (by >25% of current values) in >75% of the area that it has already invaded

B. Moderate significance. Local range expanding at a moderate rate (e.g., area occupied likely to increase by 50% in 10 years or to double within 50 years) and/or species abundance increasing significantly (by >25% of current values) in 25%-75% of the area that it has already invaded

C. Low significance. Local range expanding slowly and/or abundance increasing significantly (by >25% of current values) in only a small portion (<25%) of the area that it has already invaded

D. Insignificant. Species abundance and local range stable or decreasing across the entire area it has already invaded within the region

U. Unknown.

14. Inherent Ability to Invade Conservation Areas and Other Native Species Habitats (6 points)

A. High significance. Regularly establishes in undisturbed portions of intact or otherwise healthy, late-successional or mature native vegetation

B. Moderate significance. Regularly establishes in mid-successional native vegetation, but may establish in late-successional or mature vegetation following minor one-time or recurrent disturbances (e.g., tree falls, hiking trails, streambank erosion); however, rarely if ever establishing in undisturbed portions of intact mature native vegetation

C. Low significance. Often establishes in areas where major natural or human-caused disturbance has occurred in the previous 20 years (e.g., post-hurricane sites, landslides, highway corridors), but seldom if ever in undisturbed areas or areas with only minor disturbance

D. Insignificant. Not known to spread significantly into conservation areas or native species habitats on its own (e.g., species may be present only along edges, or may persist from former cultivation)

U. Unknown.

15. Similar Habitats Invaded Elsewhere (9 points)

Of the six EPA Level 3 Ecoregions that occur in Nebraska, how many have plant occurrences outside of their Nebraska portion?

A. High significance. Present in 4+ biogeographic units.

B. Moderate significance. Present in 3 biogeographic units.

C. Low significance. Present in a 2 biogeographic units.

D. Insignificant. Present in only 0,1 biogeographic unit.

U. Unknown.

16. Reproductive Characteristics (9 points)

The following are some reproductive characteristics typical of invasive plant species; consider which of these characterize this species.

- Produces over 1,000 seeds or spores per plant annually
- Reproduces more than once per year
- Grows more rapidly to reproductive maturity than most plants of its lifeform
- Reproduces readily both vegetatively and by seed or spores
- Has seeds (or spores) that remain viable in soil for three or more years
- Has quickly spreading rhizomes or stolons that may root at nodes
- Resprouts readily when broken, cut, grazed, or burned
- Fragments easily, with fragments capable of dispersing and subsequently becoming established
- Has other comparable reproductive factors suggesting potential aggressiveness (Explain in comments)

A. High significance. Extremely aggressive (e.g., strongly exhibits three or more of the above characteristics)

B. Moderate significance. Moderately aggressive (e.g., strongly exhibits two of the above characteristics)

C. Low significance. Somewhat aggressive (e.g., strongly exhibits one of the above characteristics, or more weakly exhibits a few)

D. Insignificant. Not aggressive (e.g., has none of the above characteristics or weakly exhibits only one)

U. Unknown.

Section IV. Management Difficulty (4 questions; 10% of I-Rank Score)

17. General Management Difficulty (18 points)

A. High significance. Managing this species normally requires a major, long-term investment of human and/or financial resources or is not possible with available technology (e.g., >\$1,500 per hectare [or >\$600/acre] per year for 5 years or more)

B. Moderate significance. Management requires a major short-term investment of human and financial resources, or a moderate long-term investment (e.g., >\$1,500 per hectare per year for less than 5 years or \$500 per hectare [\$200/acre] per year for 5 years or more)

C. Low significance. Management is relatively easy and inexpensive; requires a minor investment in human and financial resources (e.g., <\$100 per hectare [\$40/acre] per year for less than 5 years)

D. Insignificant. Managing this species is not necessary (e.g., species does not persist without repeated human disturbance and/or reintroduction)

U. Unknown.

18. Minimum Time Commitment (15 points)

- A. High significance.** Control requires at least 10 years
- B. Moderate significance.** Control requires 5-10 years
- C. Low significance.** Control requires 2-5 years
- D. Insignificant.** Control (if needed) can normally be accomplished within 2 years
- U. Unknown.**

19. Impacts of Management on Native Species (15 points)

- A. High significance.** Management impacts often severe, with the only effective methods for managing this species normally causing significant and persistent reductions in the abundance of native species (>75% of the time)
- B. Moderate significance.** Management impacts moderate, with the only effective methods for managing this species reducing native species abundance or causing other unacceptable damage 25-75% of the time
- C. Low significance.** Management impacts minor, with the only effective methods causing significant persistent reductions in native species abundance <25% of the time
- D. Insignificant.** Management impacts insignificant or rare, with effective control methods rarely or never causing significant reductions in native species abundance, or causing only ephemeral reductions (lasting <2 years)
- U. Unknown.**

20. Accessibility of Invaded Areas (3 points)

- A. High significance.** Accessibility problems high, with many invaded areas >30% of area it infests not accessible for treatment (e.g., they are on very steep slopes or canyon walls, in roadless areas, along remote shorelines, or on private lands where permission to enter is difficult to obtain)
- B. Moderate significance.** Accessibility problems medium, with a substantial percentage of the area invaded by this species inaccessible (5-30% of the area it infests)
- C. Low significance.** Accessibility problems low, with a significant but relatively small percentage of the area invaded by this species inaccessible (<5% of area it infests)
- D. Insignificant.** Accessibility problems insignificant or rare, with little or none of the area infested by this species inaccessible
- U. Unknown.**

The Nebraska Invasive Species Project. “I-Rank” Non-Native Plant Species Risk Assessment.

Survey Answer packet.

Please read instructions on page 4 of instruction packet and use questions/answers on page 5 to determine answers for each question.



Justin Williams
Nebraska Cooperative Fish and Wildlife Research Unit–USGS
University of Nebraska-Lincoln
422 Hardin Hall
Lincoln, Nebraska 68583-0984
jwillibird@yahoo.com
www.snr.unl.edu/invasives

Nebraska Cooperative Fish & Wildlife Research Unit

School of Natural Resources
Institute of Agriculture and Natural Resources
University of Nebraska-Lincoln
422 Hardin Hall
Lincoln NE 68583-0984
PH: 402-472-0449 FAX: 402-472-2722



To: **Appendix C-** Expert Opinion Survey Information

Dear _

I am writing you to inform you about The Nebraska Invasive Species Project and kindly ask for your assistance.

The Nebraska Invasive Species Project is a three-year project focused on providing resources to the public and private sectors regarding monitoring, mapping, risk and management of invasive species across the state of Nebraska. Among other project goals, we are also conducting research to provide information for management applications and to create maps of non-native species actual and potential range.

Currently, I'm working on a research project that aims to prioritize or rank potentially invasive plant species of Nebraska by assessing them for qualities related to invasiveness. The method is called the "I-Rank" species assessment protocol (Morse et al. 2004), which I have adapted specifically for Nebraska. The assessment consists of 20 questions and specific answer criteria covering a range of topics such as ecological impact, distribution and abundance, and management difficulty. Some of the questions are more easily answered than others. Fortunately, answer ranges or even answers of "unknown" are acceptable and can be used to estimate uncertainty in the final I-Rank score. However, three of the questions are too difficult for me to estimate. This is why my graduate committee has suggested I request your expert opinion in the attached survey. Although the survey questions are likely difficult to answer precisely, eliminating one or more of the possible answers will be helpful to the final results by reducing the uncertainty associated with the species I-Rank scores.

In the following pages I provide additional background information about my research project, the I-Rank methods, and instructions for completing the survey. Thank you for taking some time from your busy schedule to complete this survey. Any help you can provide is much appreciated. The answers from completed surveys will be assembled, analyzed, and used to

complete the I-Rank risk assessment. I will be sure to provide you a copy of the final assessment.

On a separate topic, I am also seeking specific location data for the species listed in the survey. If you have access to database or computerized records for these non-native plant species, they would greatly enhance my modeling efforts. These data will be helpful with parts of the I-Rank risk assessment as well as my predictive spatial model.

Please contact me with any questions.

With Sincere Thanks,

Justin Williams

Nebraska Cooperative Fish and Wildlife Research Unit-USGS

University of Nebraska-Lincoln

jwillibird@yahoo.com

www.snr.unl.edu/invasives

NatureServe, in cooperation with The Nature Conservancy and the U.S. National Park Service, developed this Invasive Species Assessment Protocol as a tool for assessing, categorizing, and listing non-native invasive vascular plants according to their impact on biodiversity in a large area such as a nation, state or province, or ecological region (Morse et al. 2004; available online at <http://www.natureserve.org/getData/plantData.jsp>) The protocol is designed to make the process of assessing and listing invasive plants objective and systematic by using a specified set of questions and requiring documentation of the scientific information used to determine each species' rank. Species are assessed one at a time for a specified "region of interest" (Nebraska) to determine an Invasive Species Impact Rank (I-Rank) categorizing the species' potential negative impact on natural biodiversity within that region as high, medium, low, or insignificant.

The Invasive Species Assessment Protocol consists of 20 weighted multiple-choice assessment questions grouped into four sections which address four major aspects of an invasive species' total impact.

Section I, Ecological Impact, is based on the premise that species with the largest negative impacts on native plant, animal, and other species populations, ecological communities, and ecosystems generally cause the most severe problems, particularly if they change ecosystem processes, or harm rare native species, keystone species, or communities of conservation significance.

Section II, Current Distribution and Abundance, is based on the premise that the greater the range and abundance of a species in a region, and the more ecological regions or habitats that it invades there, the greater the overall damage it can cause.

Section III, Trend in Distribution and Abundance, is based on the premise that species with a high potential for further spread have the potential to cause greater damage, especially if they are likely to spread to distant but currently uninfested portions of the region of interest. The questions in this section therefore assess the likelihood and rate at which the species (if not controlled) will spread to new areas and/or increase in abundance within areas it already occupies.

Section IV, Management Difficulty, is based on the premise that a species that is difficult to manage (control or prevent from spreading) will have a greater chance of causing significant damage because it is more likely to persist and spread.

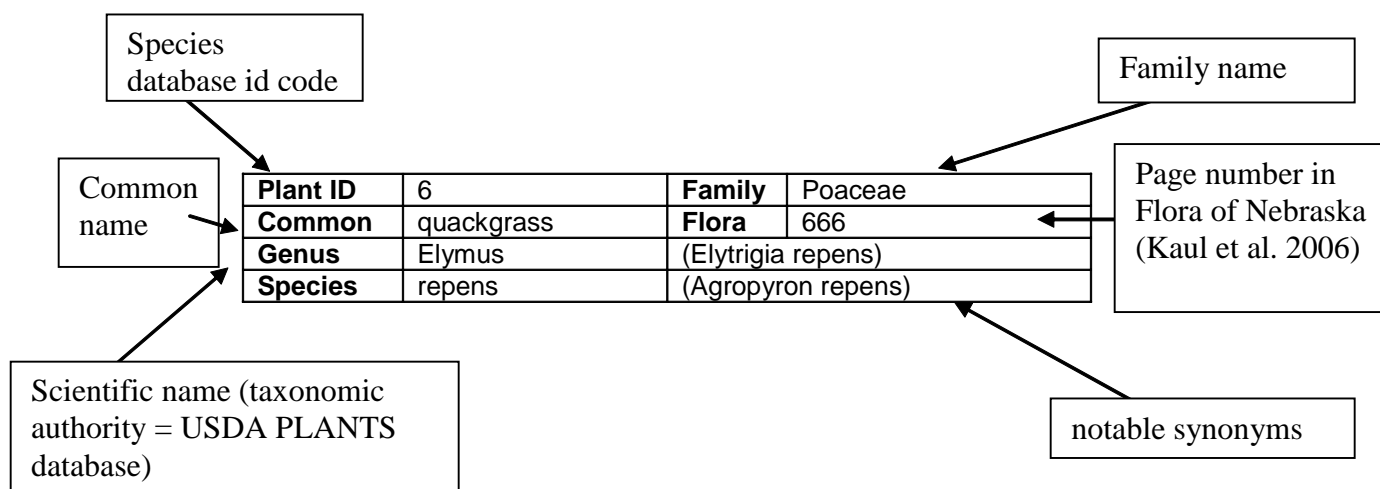
Each question has five possible precise answers: A, B, C, D, or U, where:

- A = High significance
- B = Moderate significance
- C = Low significance
- D = Insignificant
- U = Unknown

If possible, a precise answer (single-letter answer) that best characterizes the species should be selected, even if it does not describe it exactly. However, answer ranges (AC [= A, B, or C], or BD [= B, C, or D]) may be used as provisional answers if assessors can eliminate at least one of the four choices (A, B, C, or D), but do not have enough information to give a more precise answer. 'U' (Unknown) should be selected only if none of the four choices can be eliminated after a reasonable attempt to answer the question.

Candidate Species Pool

I used the following criteria to assemble the candidate pool of species. First I selected all plant species currently listed on the state noxious list and all species from the Nebraska Weed Control Association “watch list” (www.neweed.org). Then I added plants that are officially listed as noxious in the surrounding six states. I included only species that currently occur in Nebraska (and that are not native to Nebraska (Rolfmeier and Steinauer 2006)). The species list was further reduced by eliminating species that were not evaluated by the Naturserve I-Rank assessment for the United States. I used the USDA PLANTS online database (<http://plants.usda.gov>) as taxonomic authority for all species’ scientific names. In the attached survey, I have provided a brief summary (see example below) for each species including page number of the species account in Flora of Nebraska (Kaul et al. 2006). The species are arranged alphabetically by Family then Genus.



Survey Instructions

The following page contains the three questions to be answered for each species on the attached survey packet. Please use the questions and answer criteria as a reference as you fill out the survey. The most precise answer (single-letter answer) that best characterizes the species should be selected. However, answer ranges (AC [= A, B, or C], or BD [= B, C, or D]) may be used if assessors can eliminate at least one of the four choices (A, B, C, or D), but do not have enough information to give a more precise answer. ‘U’ (Unknown) should be selected only if none of the four choices can be eliminated after a reasonable attempt to answer the question. **The answer should be left blank (i.e., not reviewed) if the question has not been considered substantially or if the assessor has limited knowledge of that species.** If possible, document your response with a text comment summarizing information considered (with examples), and include citations to information sources.

Survey Questions-

1. Proportion of Current Nebraska Range Where Species Is Negatively Impacting Biodiversity

Within what proportion of the species' generalized range in Nebraska is the species causing noticeable negative impacts on biodiversity? [note: generalized range here is defined as "the entire generalized range where the species is present within Nebraska as a non-native outside cultivation, not just the range where it has its greatest impacts. The area of the generalized range is usually much greater than actual acreage infested."]

A. High significance. Impacts occur in >50% of the species' current generalized range in Nebraska.

B. Moderate significance. Impacts occur in 20 - 50% of the species' current generalized range

C. Low significance. Impacts occur in 5 - 20% of the species' current generalized range

D. Insignificant. Impacts occur in <5% of the species' current generalized range in region

U. Unknown.

2. Current Trend in Total Range within Nebraska

What is the trend in the species generalized range in Nebraska? [note: generalized range here is defined as "the entire generalized range where the species is present within Nebraska as a non-native outside cultivation, not just the range where it has its greatest impacts. The area of the generalized range is usually much greater than actual acreage infested."]

A. High significance. Range expanding in most or all directions, and/or spreading into new portions of Nebraska.

B. Moderate significance. Range increasing in some directions but not most or all.

C. Low significance. Range stable, or areas of range contraction balancing areas of expansion.

D. Insignificant. Range decreasing.

U. Unknown.

3. Local Range Expansion or Change in Abundance

Is the species increasing in abundance (cover, density, frequency, etc.) within its current range in Nebraska and/or locally expanding within or at the edges of this range (peripheral expansion, generally <100 km or 60 miles), based on trends of the past 10-20 years?

A. High significance. Local range and/or species abundance increasing rapidly (e.g., area occupied likely to double within 10 years in most areas where it doesn't already fully occupy its potential habitat), and/or abundance increasing significantly (by >25% of current values) in >75% of the area that it has already invaded.

B. Moderate significance. Local range expanding at a moderate rate (e.g., area occupied likely to increase by 50% in 10 years or to double within 50 years) and/or species abundance increasing significantly (by >25% of current values) in 25%-75% of the area that it has already invaded.

C. Low significance. Local range expanding slowly and/or abundance increasing significantly (by >25% of current values) in only a small portion (<25%) of the area that it has already invaded

D. Insignificant. Species abundance and local range stable or decreasing across the entire area it has already invaded within the region

U. Unknown.

Completed survey example:

Plant ID	7	Family	Brassicaceae
Common	garlic mustard	Flora	259
Genus	Alliaria		
Species	petiolata		

1. Proportion Nebraska Range where Negatively Impacting Biodiversity

Answer: **AB**

Comments:

Negatively impacts native plant species, likely others.

2. Current Trend in Total Range within Nebraska

Answer: **A**

Comments:

Has spread quickly in last 5 years.

3. Local Range Expansion or Change in Abundance in Nebraska

Answer: **A**

Comments:

Now occurs in great abundance in Indian Caves State Park and other locales in Eastern Nebraska.

References:

Kaul, R.B., D.M. Sutherland, and S.B. Rolfsmeier. 2006. The Flora of Nebraska. School of Natural Resources, University of Nebraska, Lincoln.

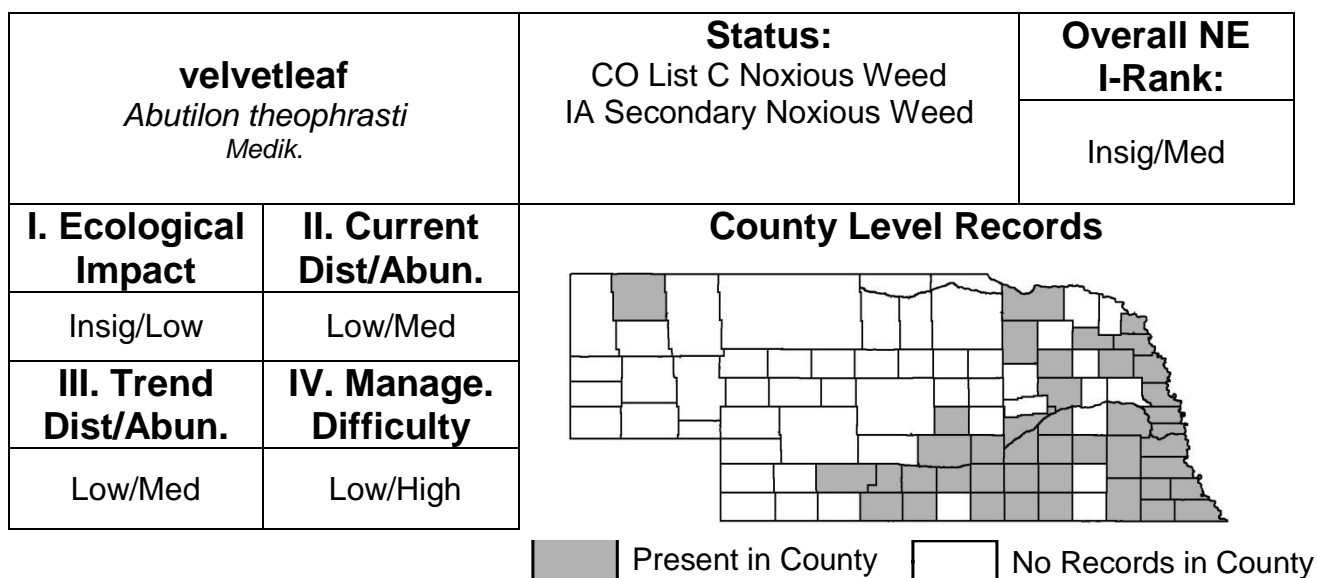
Morse, L.E., Randall, R.M., Benton, N., Hiebert, R. and S. Lu. 2004. An Invasive Species Assessment Protocol: Evaluating Non-Native Plants for Their Impact on Biodiversity. Version 1. NatureServe, Arlington, Virginia.

Rolfsmeier, S. and G. Steinauer. 2006. Vascular Plants of Nebraska. Nebraska Natural Heritage Program and Nebraska Game and Parks Commission. Available online at: <http://www.calmit.unl.edu/invasives/vascularplants.htm>

Appendix D- I-Rank Species Summaries-

Maps depicting counties with known collections (Kaul et al. 2006) and regulatory status in Nebraska and six surrounding states (University of Montana 2006) are provided as reference. Expert opinion and Weed Management Area (WMA) survey comments are separated by semicolon. Comments received from WMAs are indicated with WMA name in parentheses following each comment.

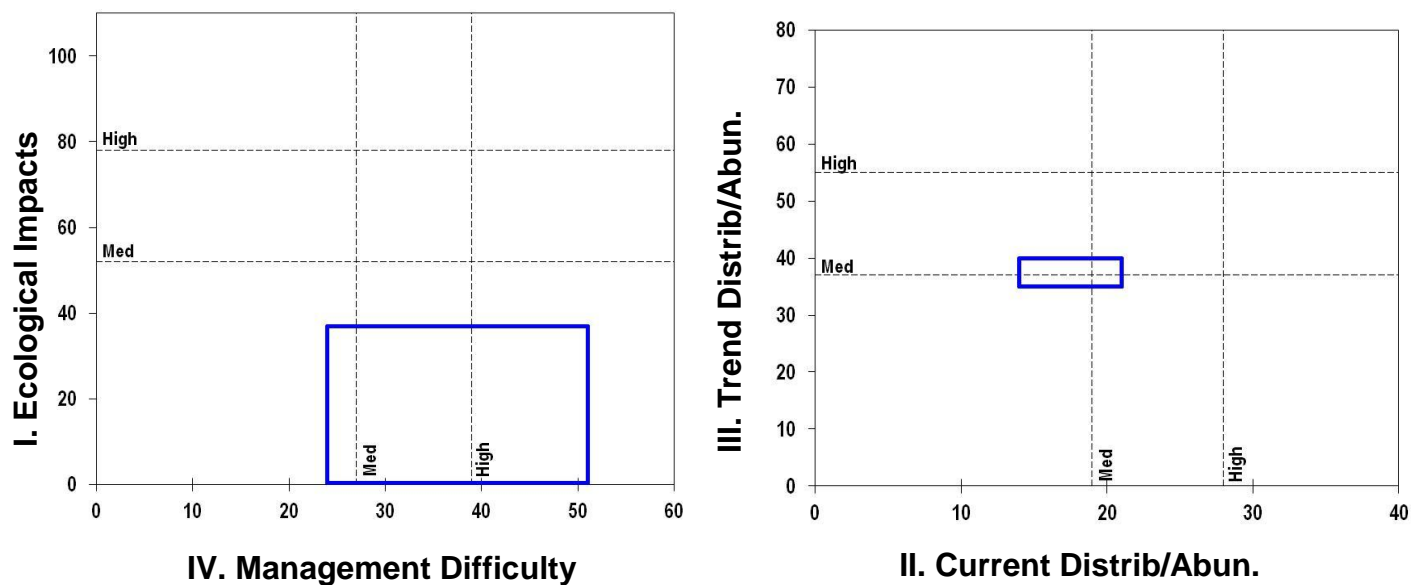
Units for all Subrank Diagram axes are in points. The scales are based on the point intervals within each Subrank (see Table 6). Boxes represent upper and lower point estimates for each Subrank. The farther the box is positioned towards the Subrank maximums in the upper, right quadrant, the greater the invasion risk associated with that species. The area of the box formed by the upper and lower estimate lines for both Subranks can be interpreted as the estimated uncertainty for that species, with larger rectangle area indicating increased uncertainty.

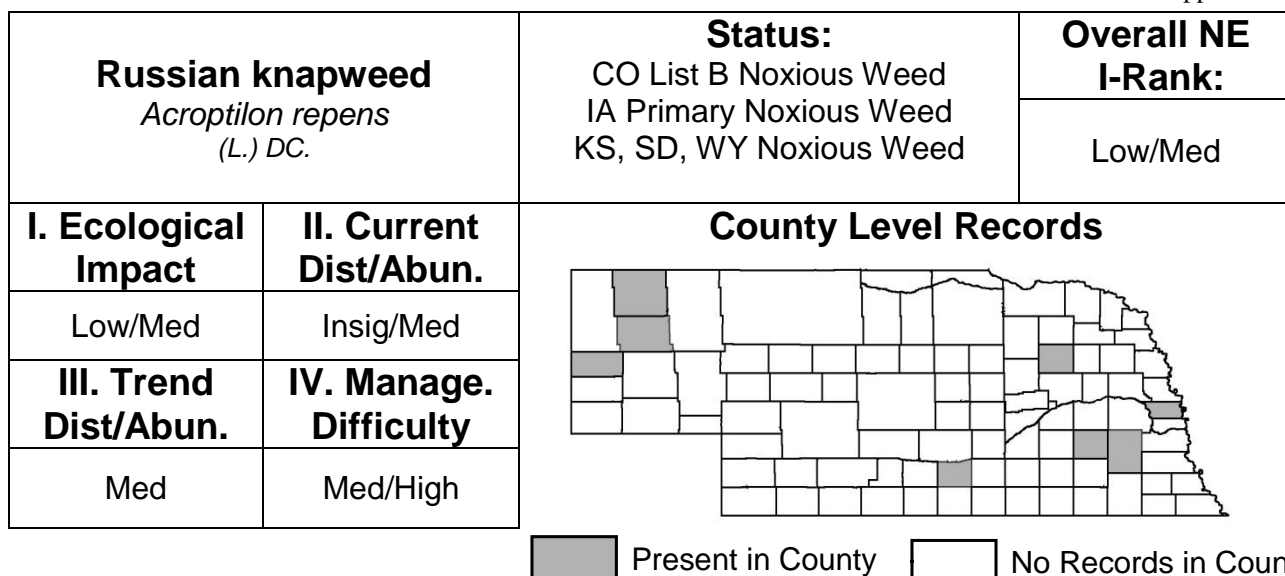


Comments:

This species is introduced from Eurasia and occurs mostly in the eastern Great Plains where it is regarded as a serious row crop weed, also occurring in waste places, pastures, and roadsides (Stubbendieck et al. 2003). Within Nebraska it occurs mostly in Eastern half, but it is spreading west (Kaul et al. 2006). Notable Survey Comments: expanding westward but unable to persist away from croplands; not in native ecosystems; crop weed, not much in rangeland; this is a weed of cultivated lands and has little to no effect on biodiversity.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

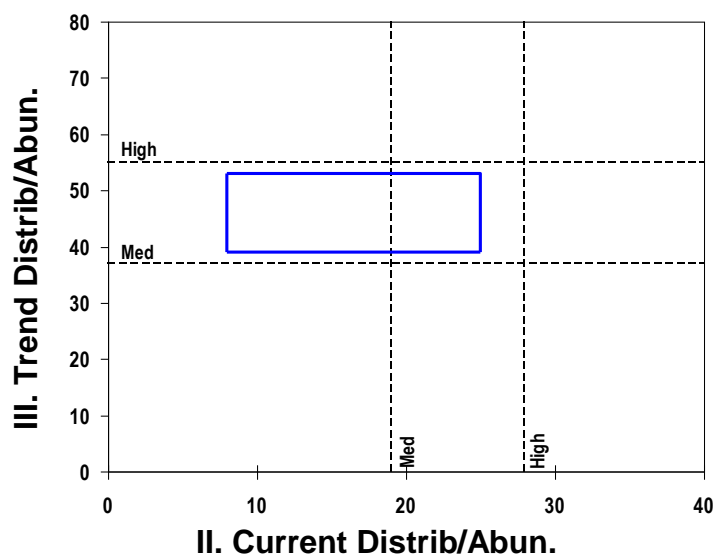
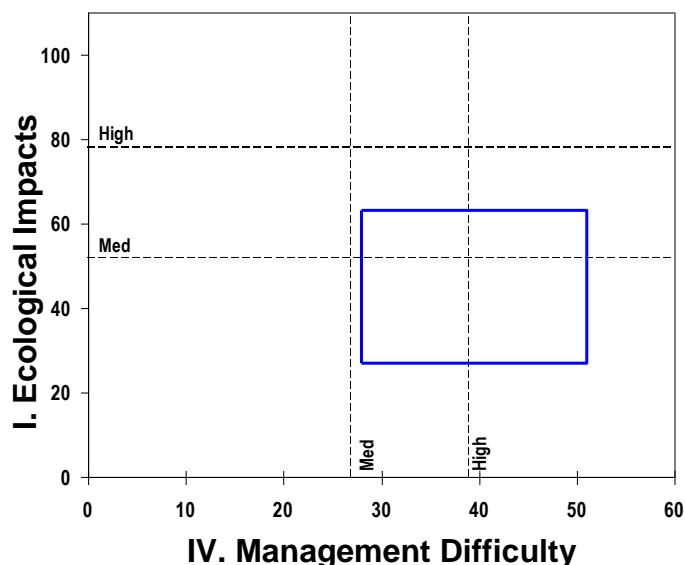


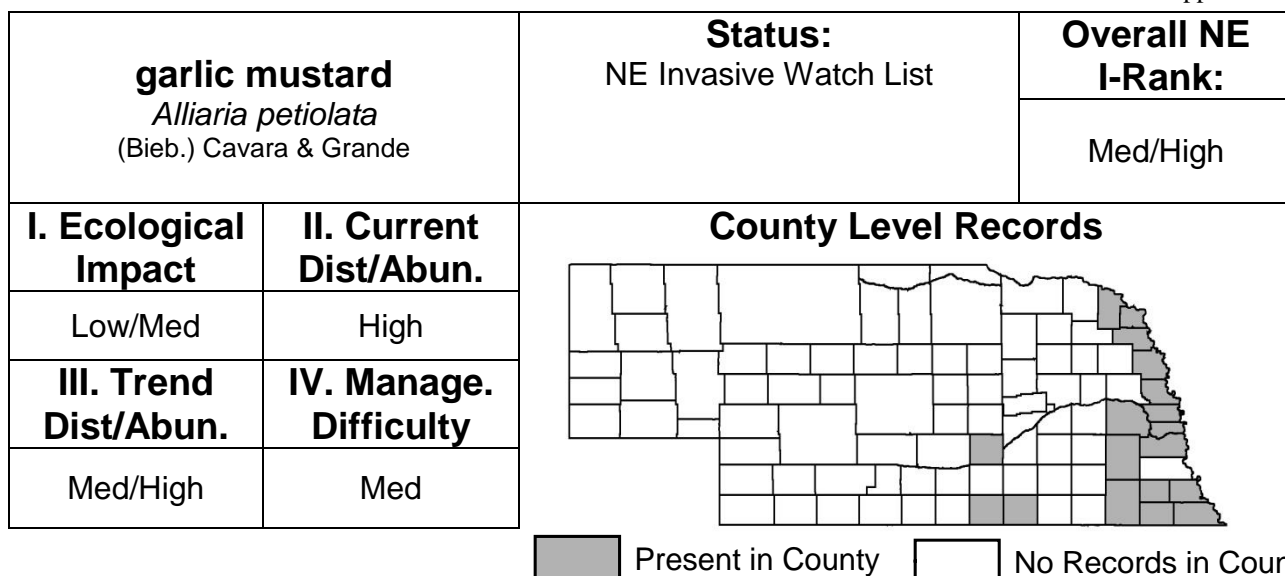


Comments:

This species is native to Eurasia and now widespread nearly worldwide. First recorded from Nebraska in Kearney County in 1931 where it was said to be a "very troublesome pest" (Rolfmeier 2007). The plant is reported to be a difficult pest to control in alfalfa, clover, pastures and occasionally row crops and has become more abundant in recent years (Stubbendieck et al. 2003). Notable Survey Comments: was expected to be a huge problem but has never lived up to expectations. I understand it is persistent where established; a few heavy infestations are known, likely to increase and become troublesome. The PRIDE WMA ranked this species appreciably higher than the other WMAs and commented: Quickly becomes a monoculture. Specifically has moved from highway ROW's to pastures. Expands if not controlled.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

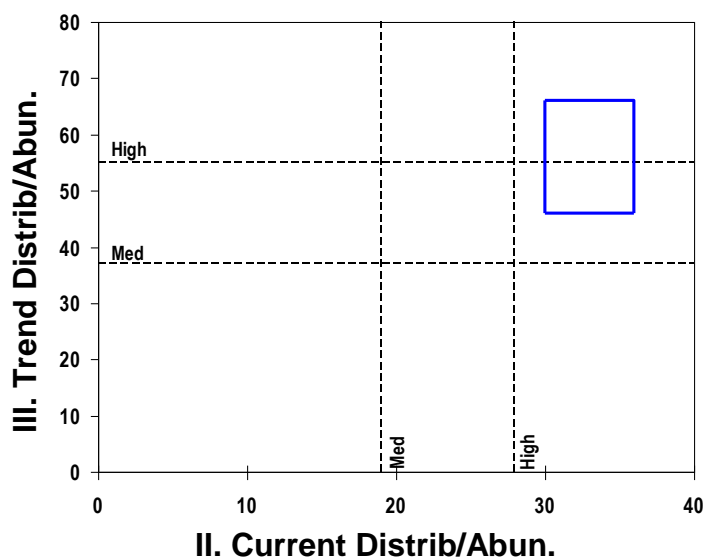
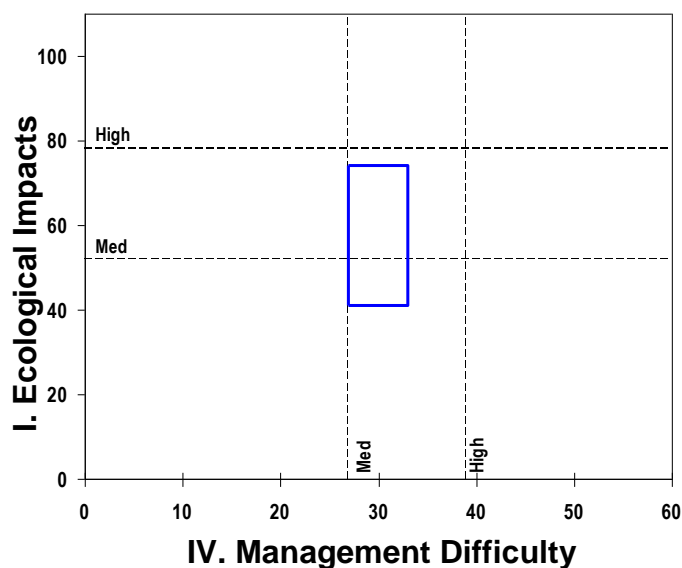


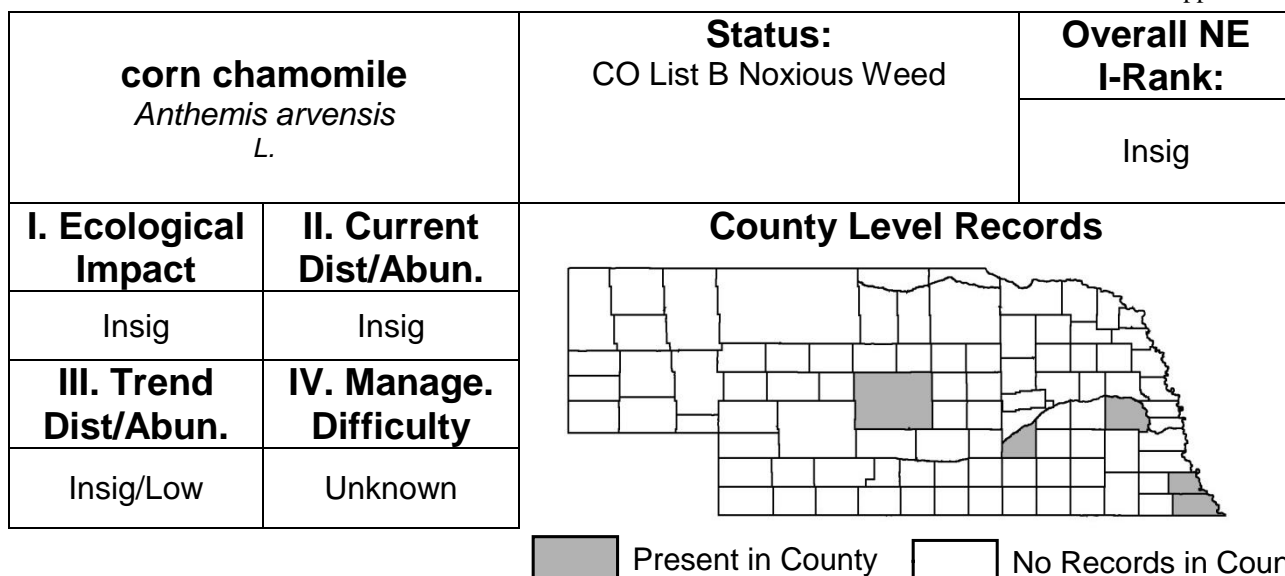


Comments:

This species is introduced from Europe and occurs mostly in Eastern Great Plains, scattered westward, in floodplains, open forests, roadsides, fields and gardens (Stubbendieck et al. 2003). First collected in Nebraska along the Republican River in Webster County in 1975 and is described as an aggressively spreading weed, especially in woodlands (Rolfmeier 2007). Kaul et al (2006) noted that it recently increased greatly in woodland habitats in Eastern Nebraska and is now of serious concern for woodland nature centers and parks. Notable Survey Comments: was taking over west end of Platte River SP in 2001. Blackbird Hill and Fontonelle Forest have mostly succumbed; Serious problem in woodlands/forests along MO River and expanding westward. Appears to be increasing dramatically in eastern NE. Currently known as far west as Hall Co. and may eventually spread across state; one small area located below diversion dam at Guide Rock in Webster County (Twin Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

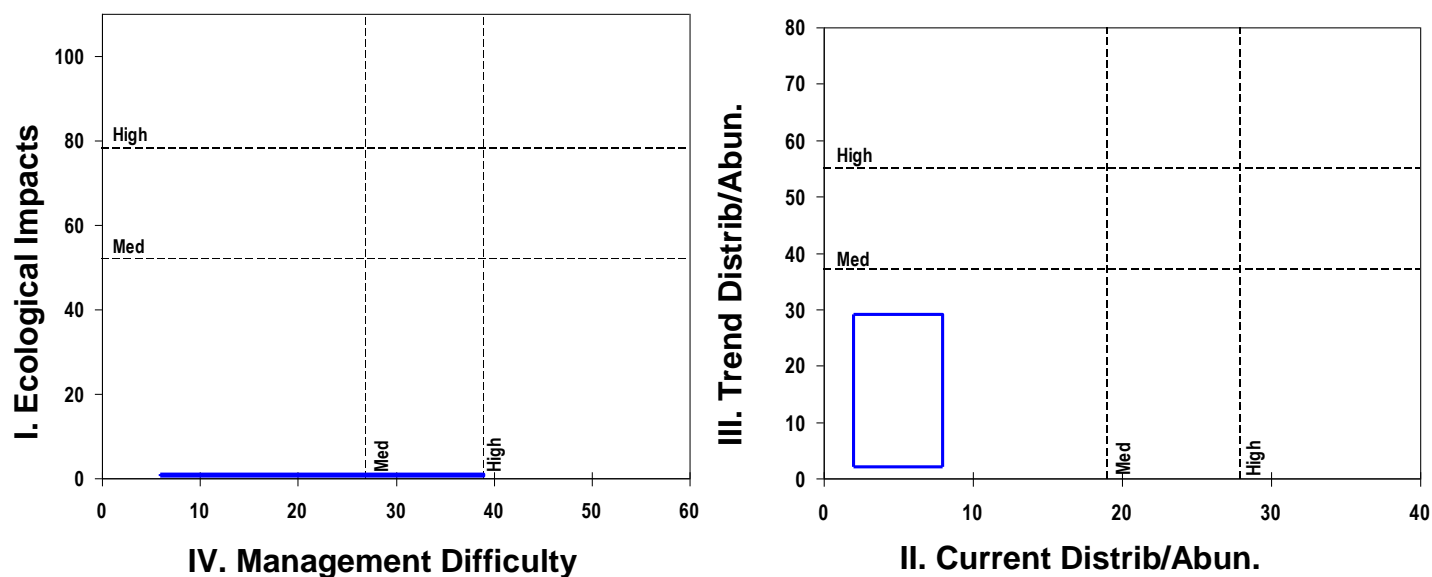


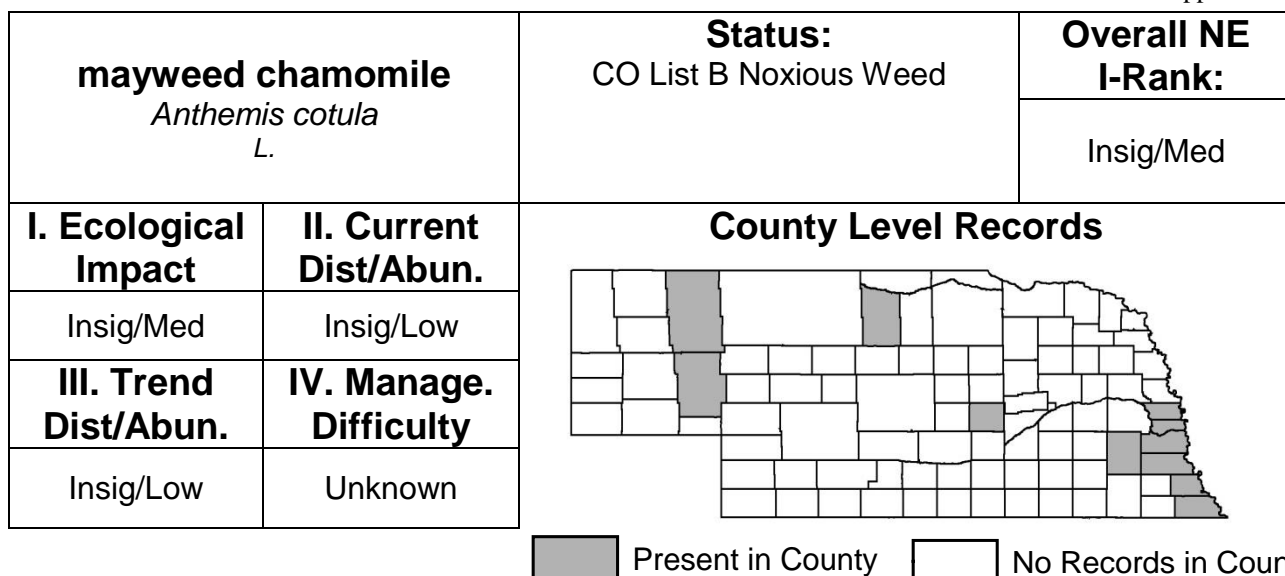


Comments:

This species is introduced from Europe, is considered a “waif” not firmly established in Nebraska, and has only been collected a few times in the state (Kaul et al. 2006). Notable Survey Comments: a rare casual alien; very uncommon in Nebraska; plants of highly disturbed areas little to no effect on biodiversity.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

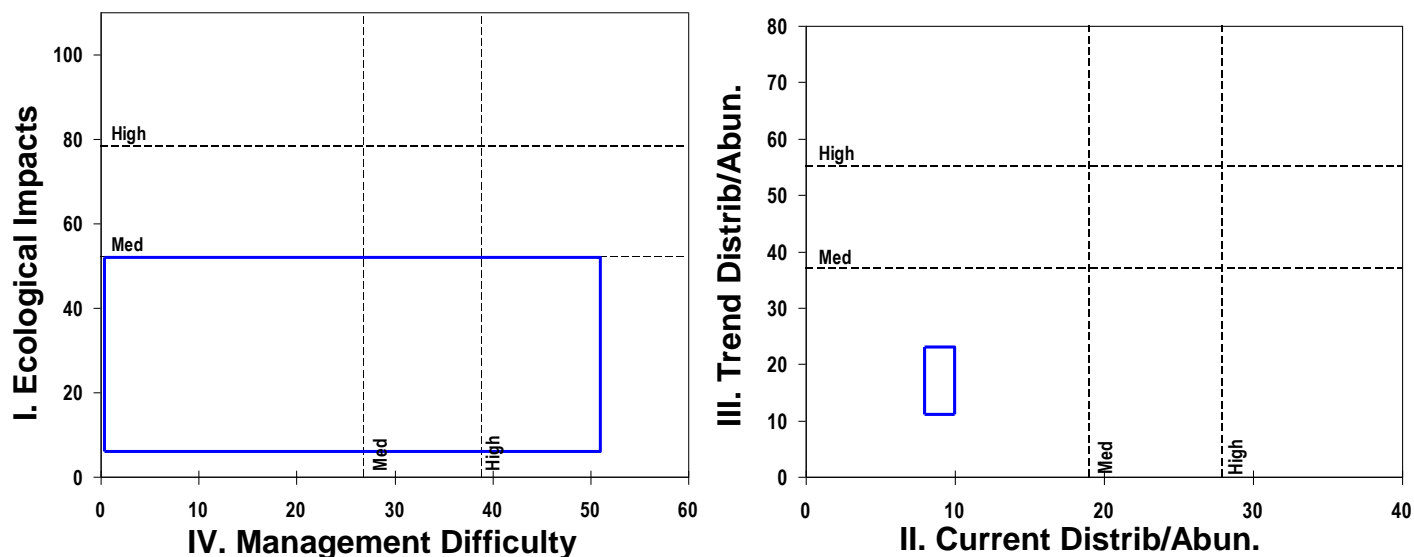


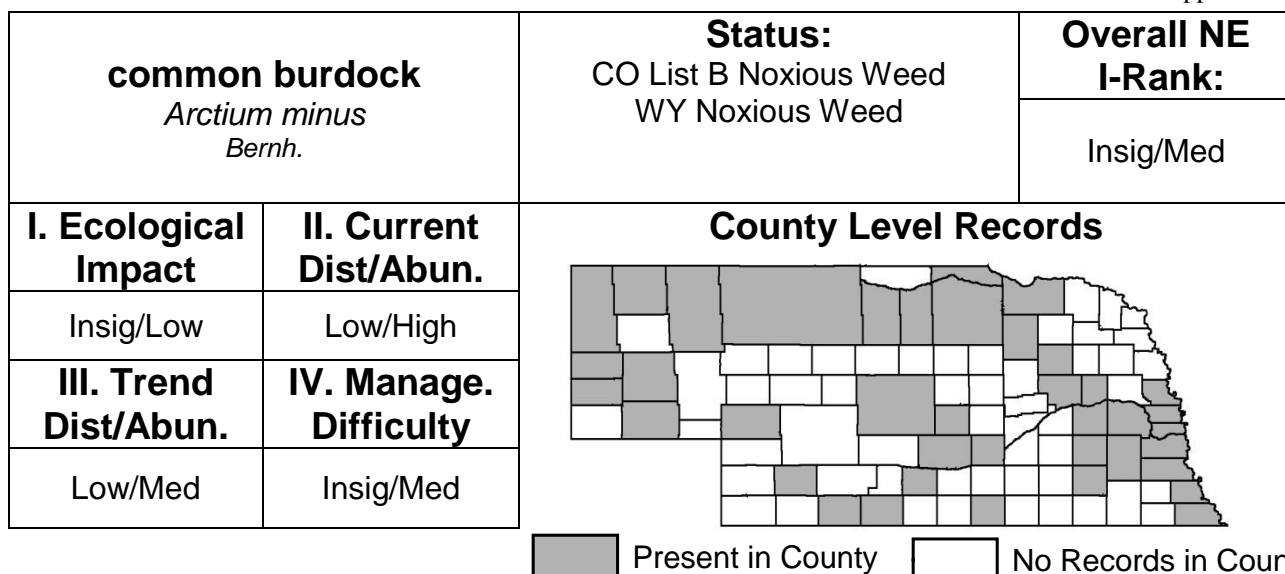


Comments:

This species introduced from Europe is not considered a serious problem where it occurs, which includes the eastern two thirds of the Great Plains in cultivated fields, abused pastures, farmsteads, barnyards, feed lots, waste areas, and roadsides (Stubbendieck et al. 2003). Kaul et al (2006) notes that Nebraska observations show it to only be a waif, seldom abundant or persisting at a site more than a year. Notable Survey Comments: Very uncommon in Nebraska.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

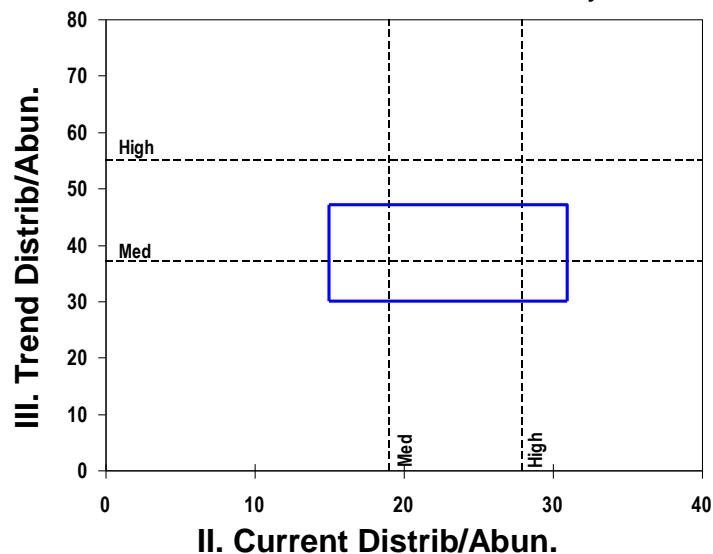
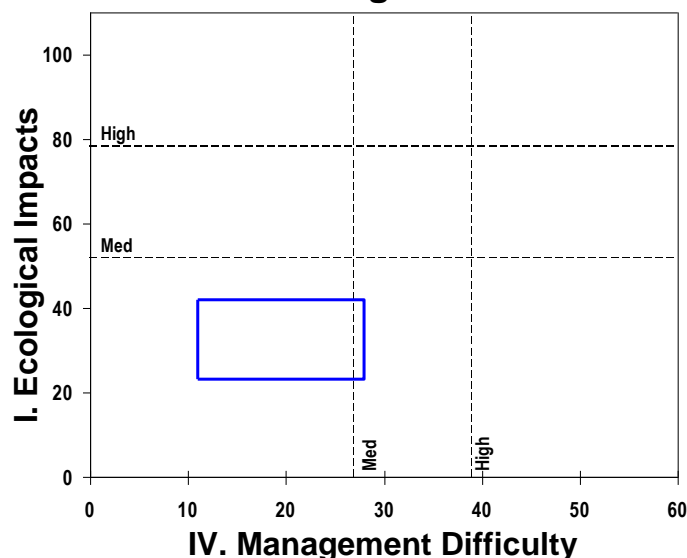


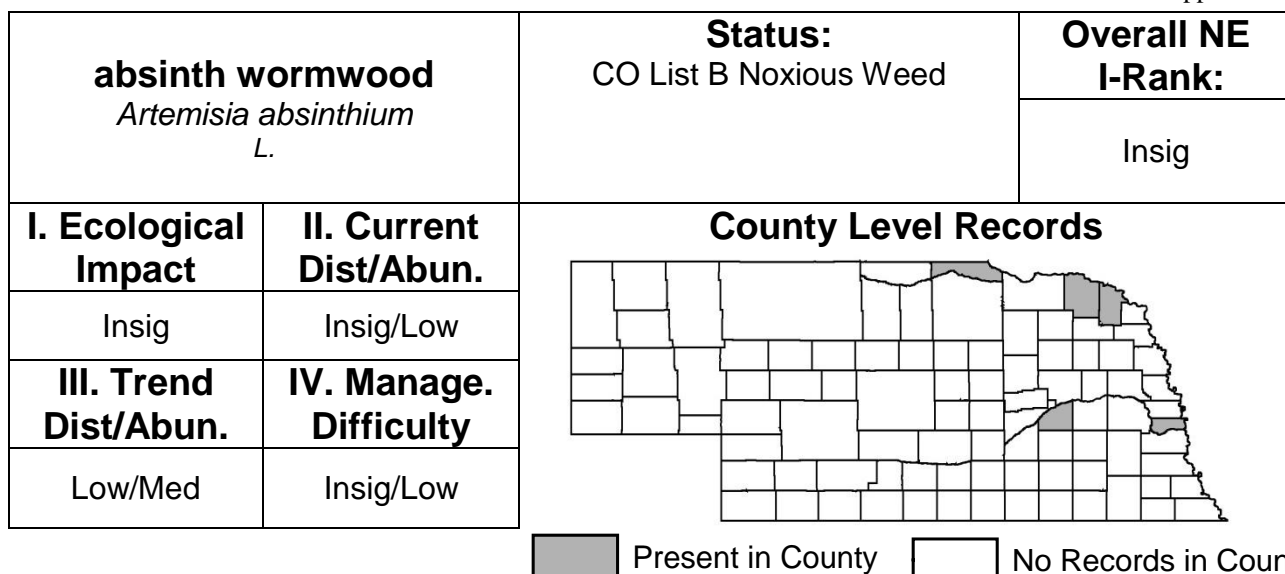


Comments:

This species native to Eurasia was documented in Nebraska by 1885 and found statewide by 1936 (Rolfmeier 2007). The plant occurs throughout the Great Plains except the northwest and southwest portions. Usually found in partial shade along roadsides, ditch banks, pastures, neglected farmland, and waste places (Stubbendieck et al. 2003). In Nebraska it often occurs in heavy, damp soils, but not in dune areas of the Sandhills (Kaul et al. 2006).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

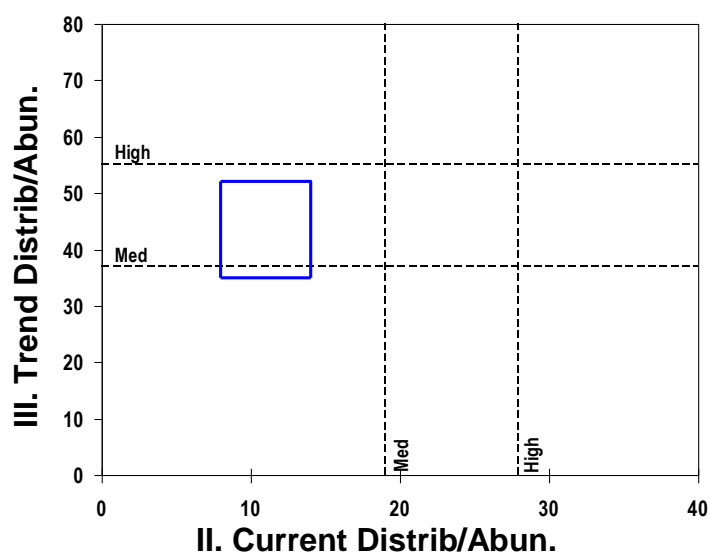
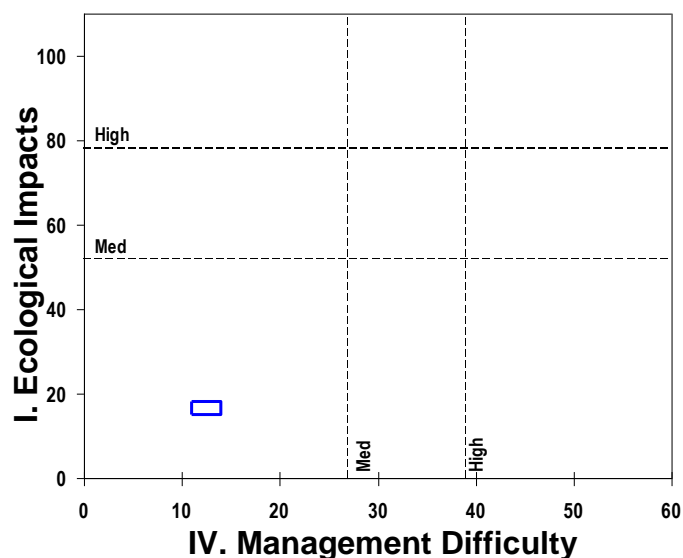


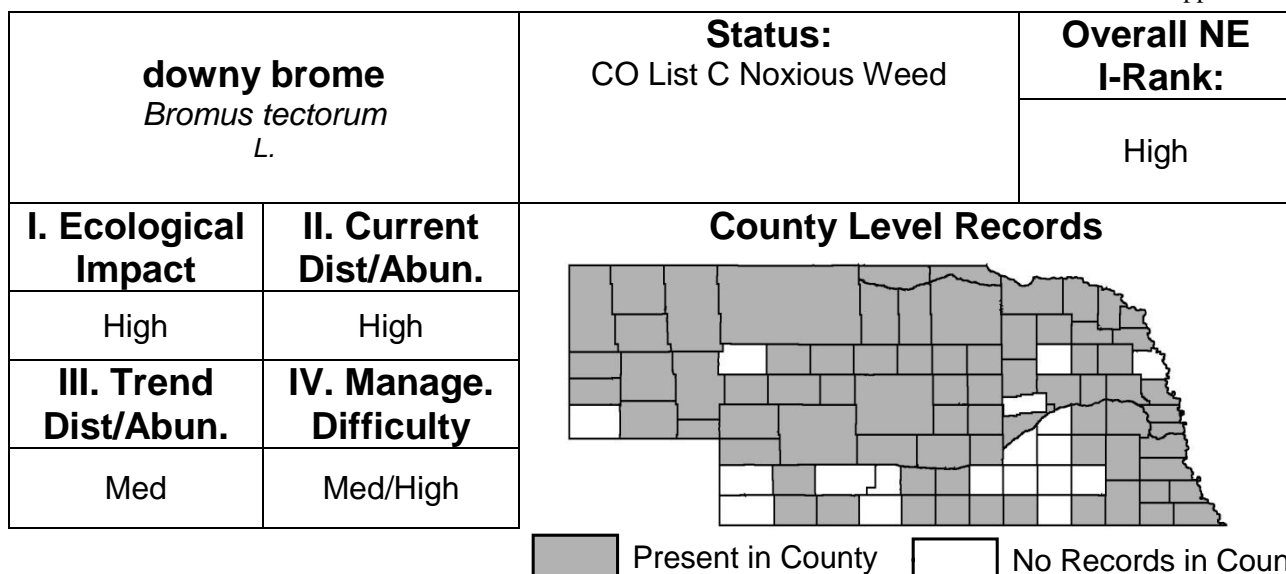


Comments:

This species is native to Europe and was first collected in northeast Nebraska in 1972. It has been observed invading disturbed sites sandbars in the Missouri River (Rolfmeier 2007). It is a more serious problem in the north central great plains (Stubbendieck et al. 2003). It is known from only a few counties in the eastern ¼ of Nebraska (Kaul et al. 2006). Notable Survey Comments: has a limited range in the state and appears to be increasing, though only in a relatively small area; not abundant except locally. Could become a problem. A serious weed in northern states, but shows little sign of becoming so in Nebraska. All WMAs declined to rank the species except the Northeast WMA.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

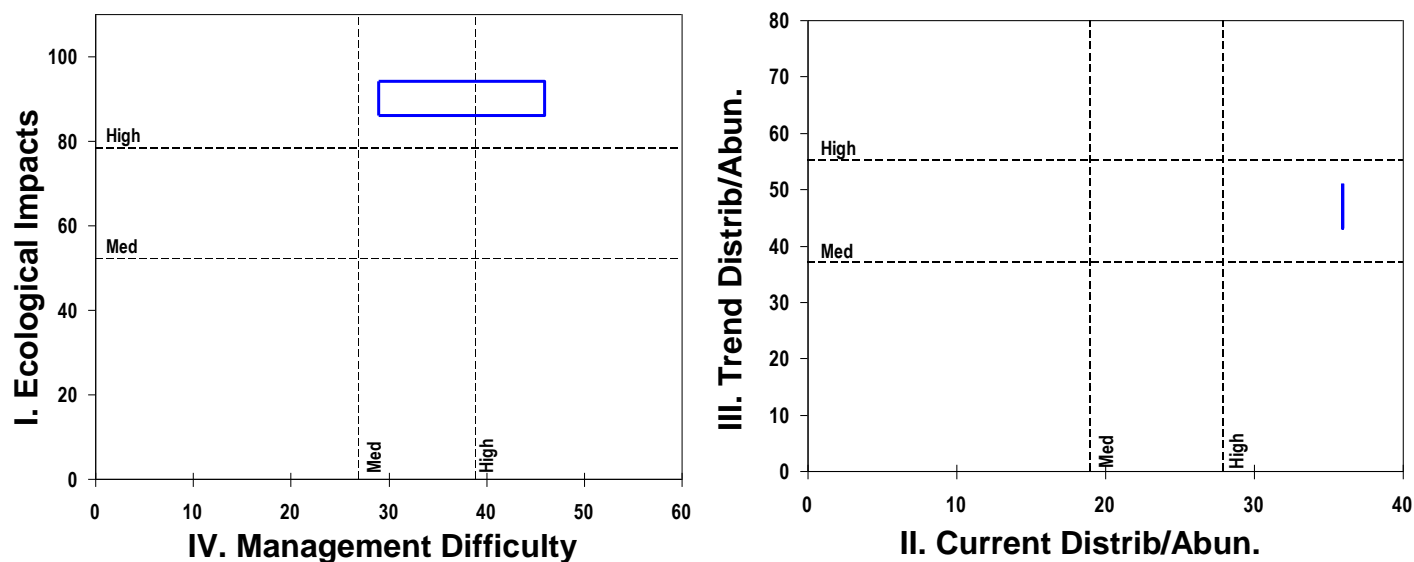




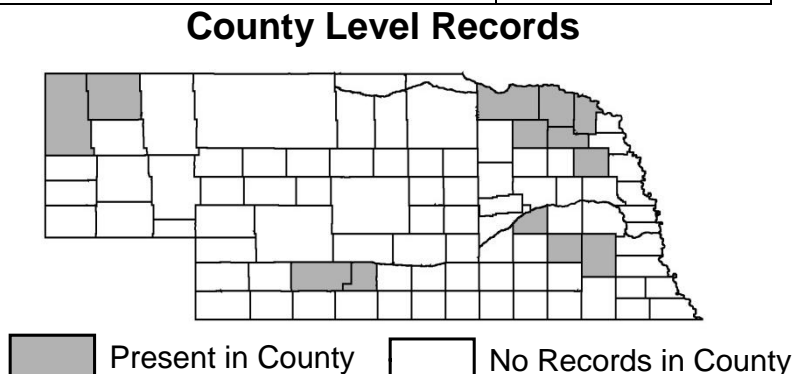
Comments:

This species is found throughout the Great Plains and can have negative impacts on livestock and create a fire hazard (Stubbendieck et al. 2003). The plant is already widespread throughout Nebraska (Kaul et al. 2006). Notable Survey Comments: range in Nebraska is not changing though there may be year-to-year variation due to climate and management practices; Highest abundance and impacts, are generally located in the western half of Nebraska; PRIDE WMA reported HIGH for proportion of range with negative impacts, current trend in range, and local change in abundance.

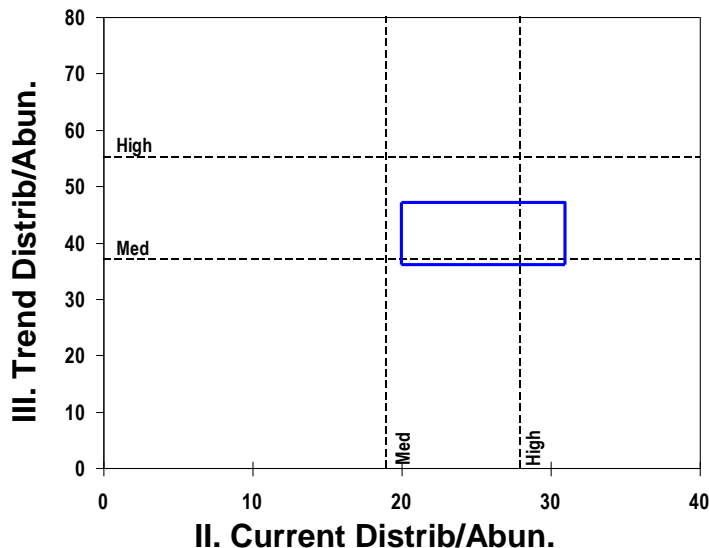
Subrank Scores- Increased box dimensions indicate increased uncertainty .

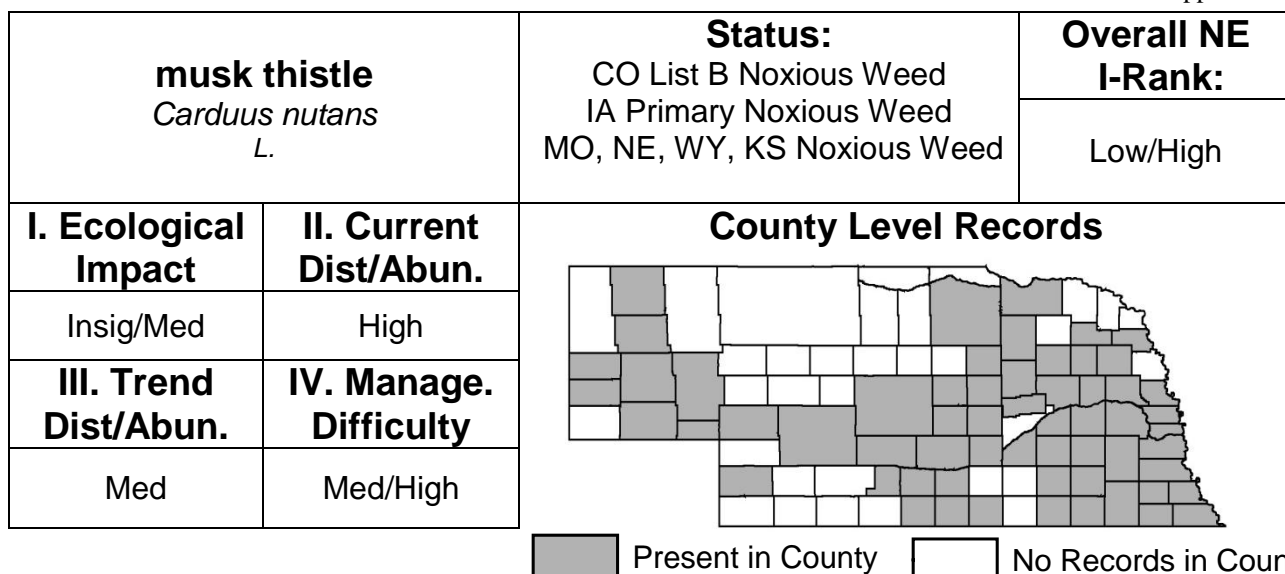


I. Ecological Impact	II. Current Dist/Abun.
Insig/Med	Med/High
III. Trend Dist/Abun.	IV. Manage. Difficulty
Low/Med	Unknown



This species is native to Eurasia and currently occurs primarily in the east/central GP, being scattered farther west, typically in pastures, and rangeland areas (Stubbendieck et al. 2003). In Nebraska the plants can be locally abundant in disturbed places and pastures and occurs mostly in the Panhandle and northeast quarter, but not in the Sandhills (Kaul et al. 2006). It is reported to form dense stands in disturbed grassland, but usually not persisting when disturbance is removed (Rolfsmeier 2007). Notable Survey Comments: appears to be increasing in range but not having a long lasting impact when it is established; never abundant, we seldom find it anymore. Seems to be decreasing; not many acres and seems to be out-competed by Canada Thistle. Most infestations in riparian areas, but spread not rapid. Small infestations stay small.

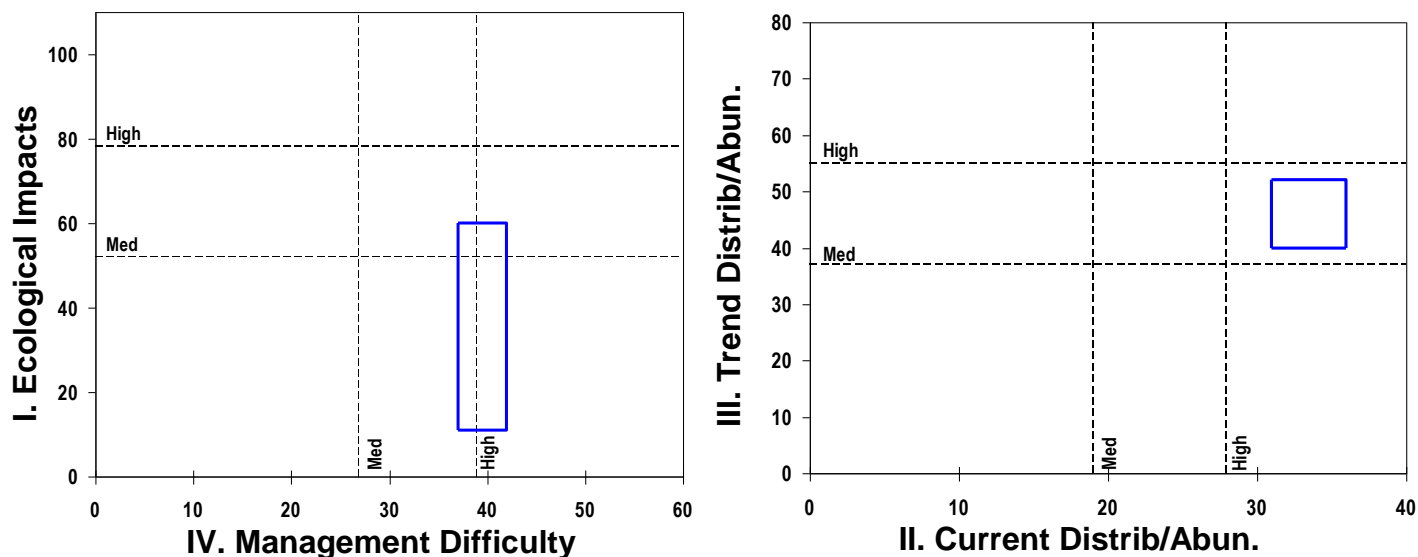


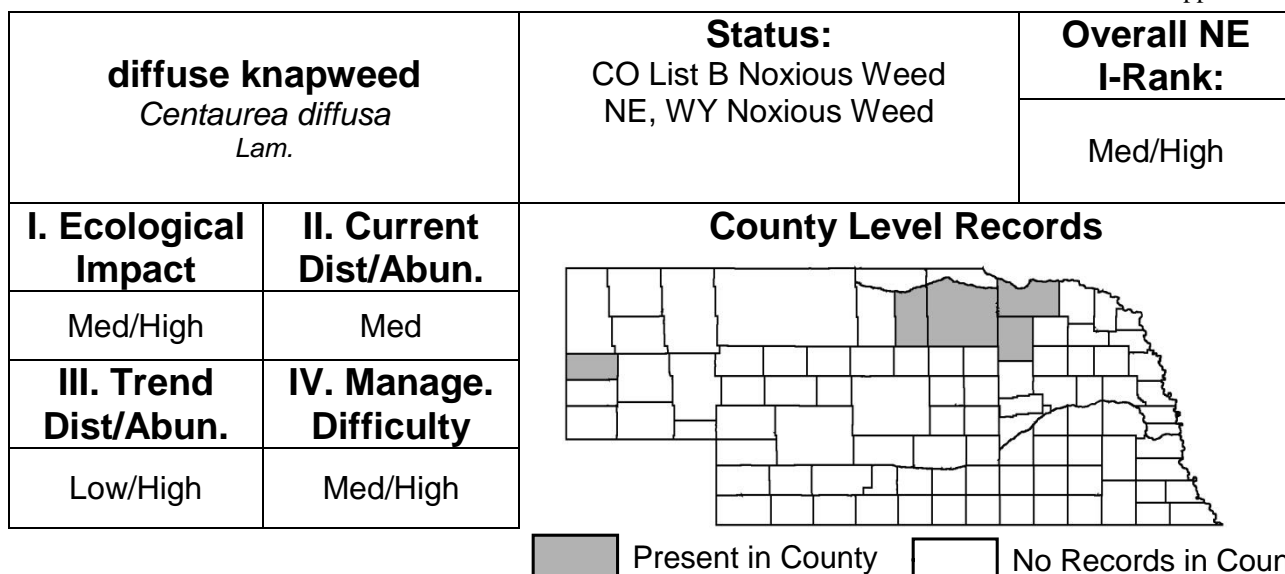


Comments:

This species' native range includes western and central Europe to western Siberia, Asia Minor and south to North Africa (Rolfsmeier 2007). It is widespread throughout the Great Plains, being especially abundant in the east-central part. In Nebraska it is common and especially troublesome in disturbed places, overgrazed pastures and meadows, abandoned farms, and feedlots. It does not occur in the Sandhills except in river bottoms. It occurs commonly in the eastern half of State and along the entire Platte River Valley (Kaul et al. 2006). Notable Survey Comments: I think it has likely expanded as far as it will, perhaps increasing in the southwest somewhat; Populations seem to be decreasing, probably due to herbicide use. Local infestations are still severe; main impacts on diversity are related to control methods, not the plant itself; this species appears to be confined to highly disturbed areas (and overgrazed pastures). Does not seem to invade areas of high diversity; has the potential to spread if not controlled. Musk thistle is taking advantage of drought and overgrazed pastures. Existing infestations expand (PRIDE); rangeland control since introduction of residual type herbicides in last decade has made significant improvement in control (Platte Valley); present in the whole WMA. Has potential to be very invasive but is controlled due to the fact it is a noxious weed in NE (Twin Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

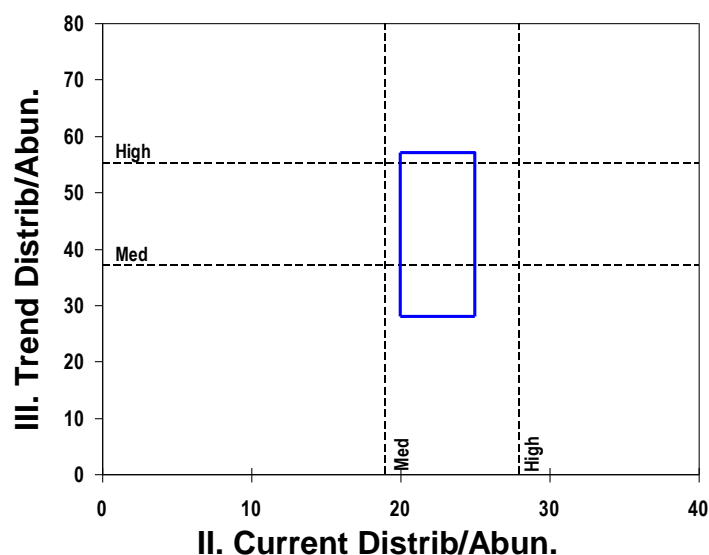
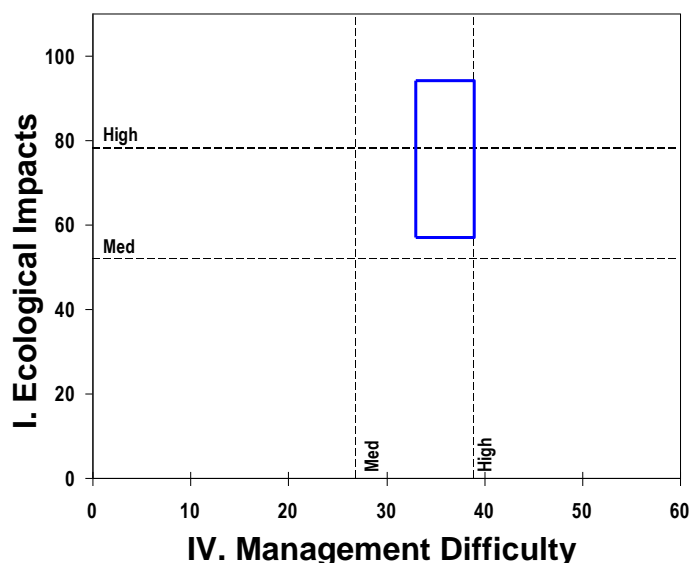


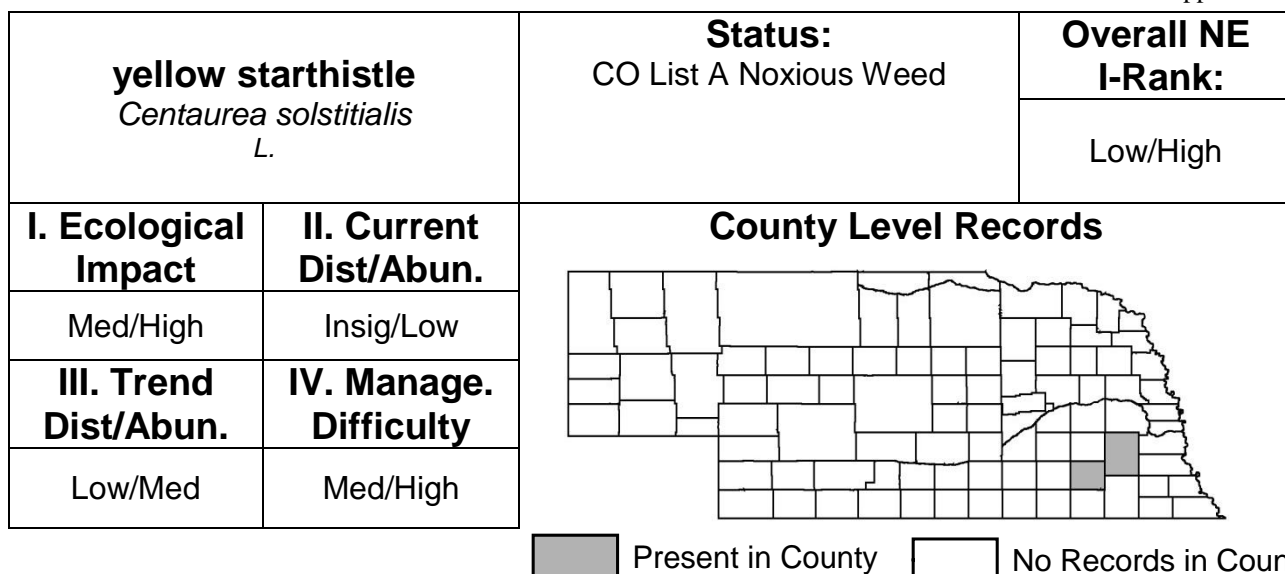


Comments:

This species is native to eastern Europe and western Asia and is described as a “prolific, allelopathic weed that can be abundant in disturbed grassland and riparian habitats, but which can also spread into undisturbed habitats” (Rolfsmeier 2007). It was first collected in Nebraska in 1990, and was observed in abundance on sandy soil at several sites near Willow Creek in Pierce County (Kaul et al. 2006). Notable Survey Comments: I have not detected significant range expansion; Only very locally common. Could become a problem, but not so yet.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

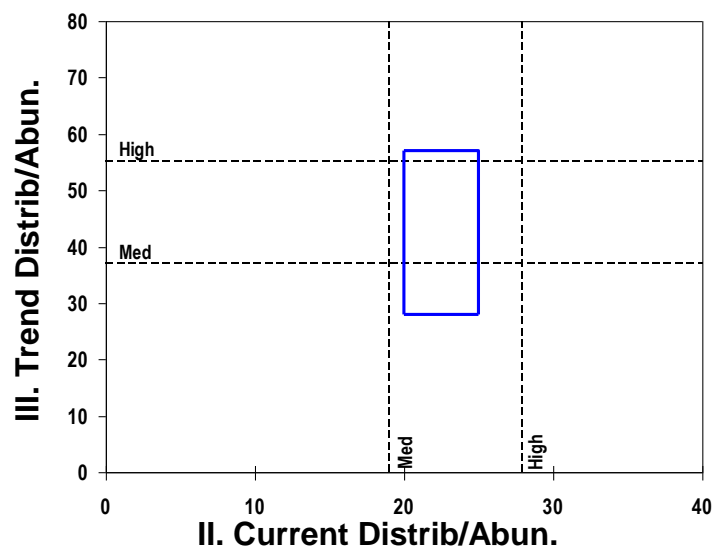
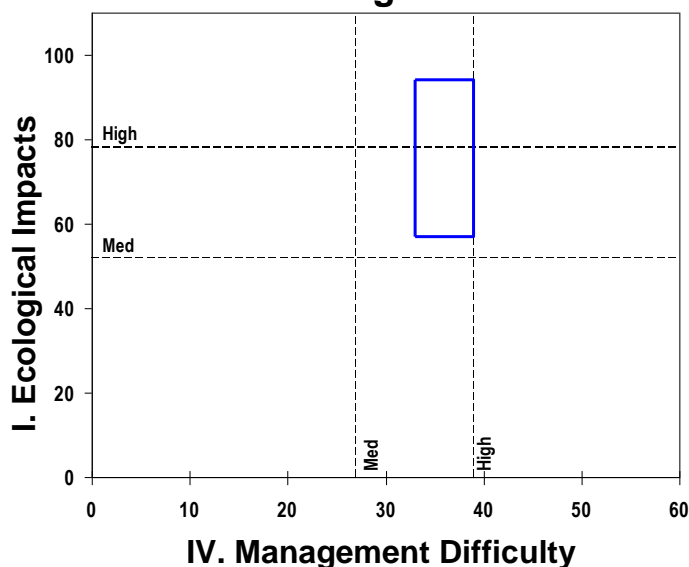


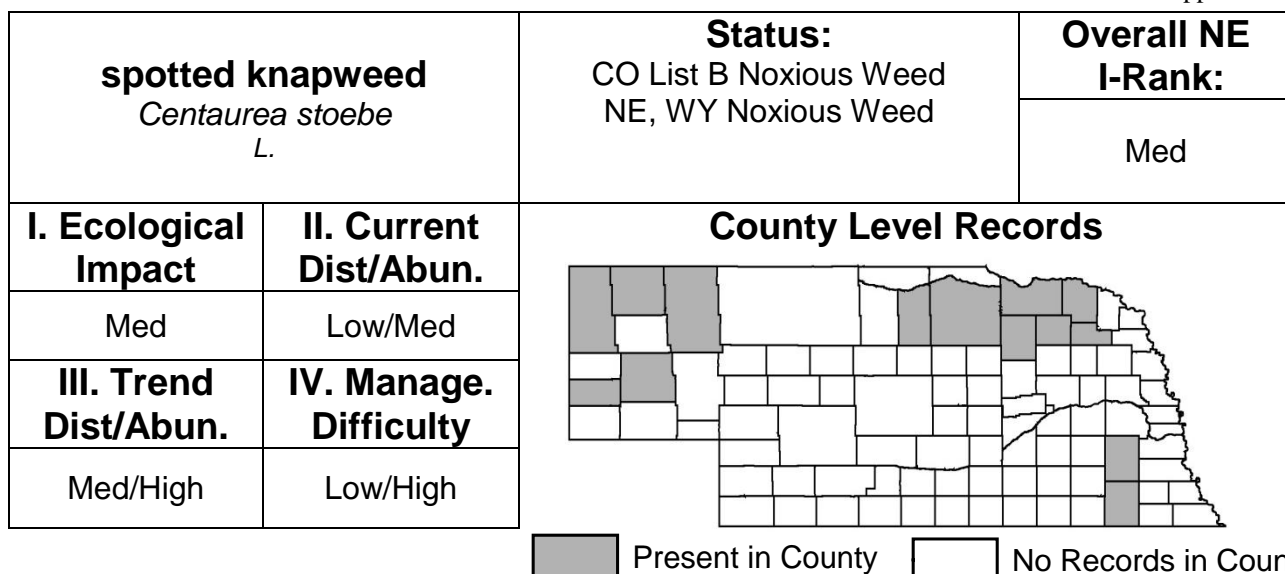


Comments:

This species, native to the Mediterranean, was collected in Nebraska in Saline and Lancaster Counties by 1908, but has not been collected since (Rolfsmeier 2007). Occurrence observations for this plant are scattered across the Great Plains on rangeland, pastures, roadsides, fields, and waste areas (Stubbendieck et al. 2003). Although a serious weed in more western states, it is considered a waif in Nebraska (Kaul et al. 2006). Notable Survey Comments: I doubt this plant, adapted to Mediterranean climate, is ever likely to reproduce here; a rare plant in Nebraska. Shows no sign of increase.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

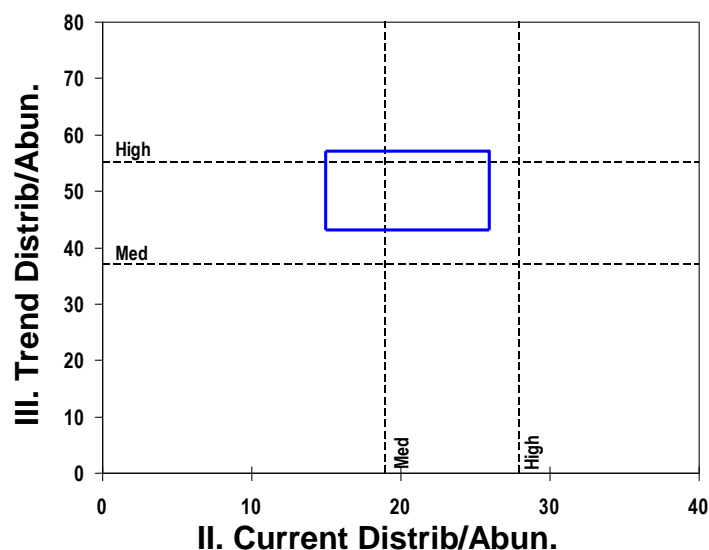
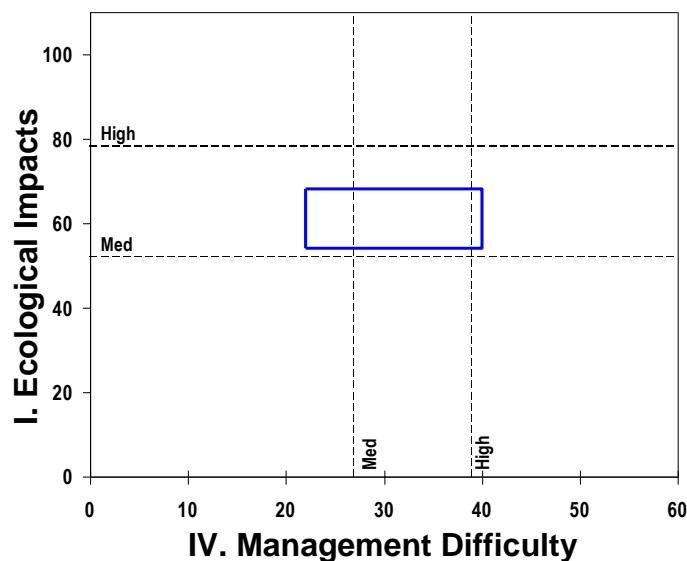


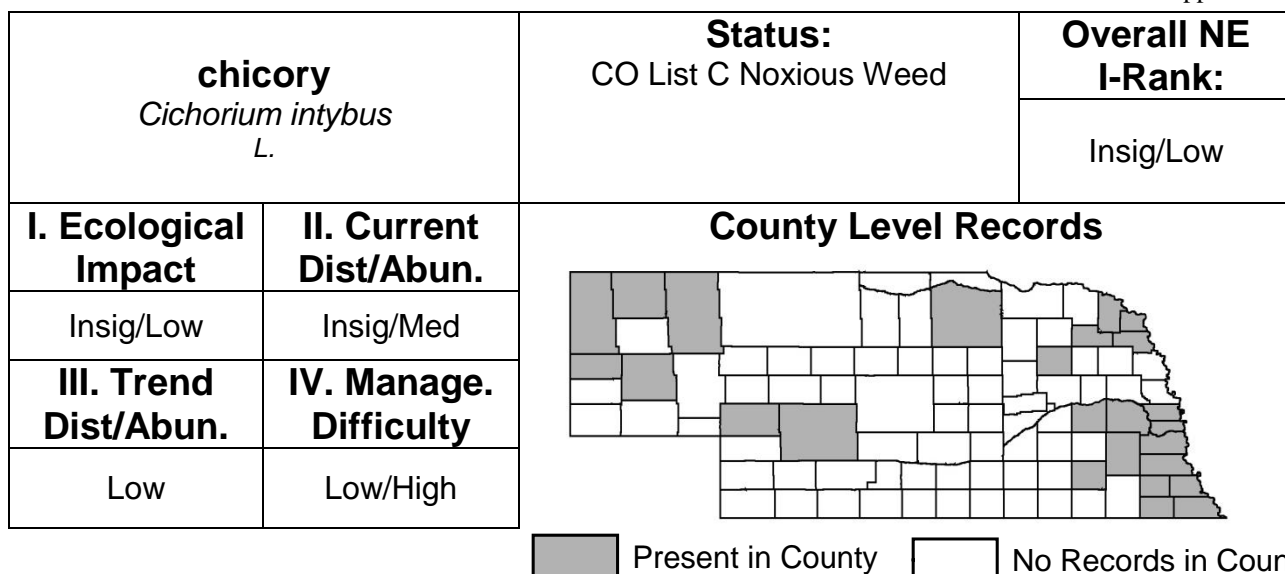


Comments:

This species is native to Europe and was collected in Nebraska by 1917, but was not noticed again until the 1980's. It seems to establish in disturbed areas; once established it can invade undisturbed sites to "devastating effect" (Rolfsmeier 2007). In Nebraska it is locally common on sandy soils of roadsides, pastures, and meadows in northern counties. It is a noxious weed that started becoming a problem in the 1990s (Kaul et al. 2006). Notable Survey Comments: appears to be spreading rapidly especially in SE Nebraska, but hasn't yet shown signs of taking over in places where it is established, as far as I can tell; Increasing and could become serious. It is a severe problem in northern states and has been so for decades.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

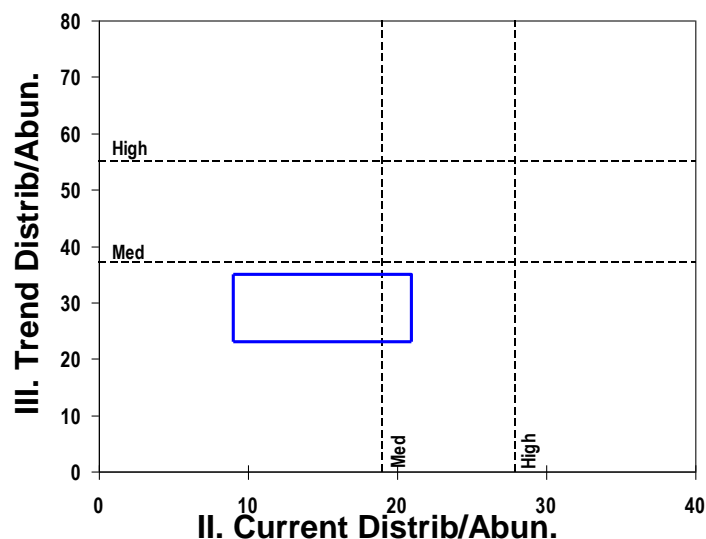
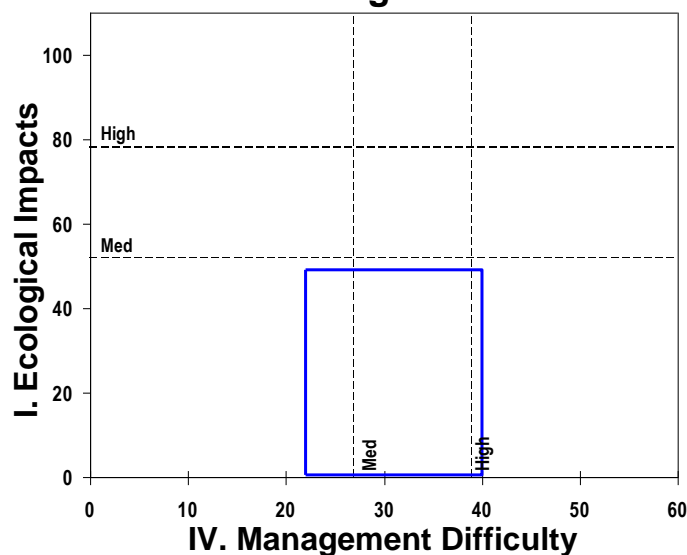


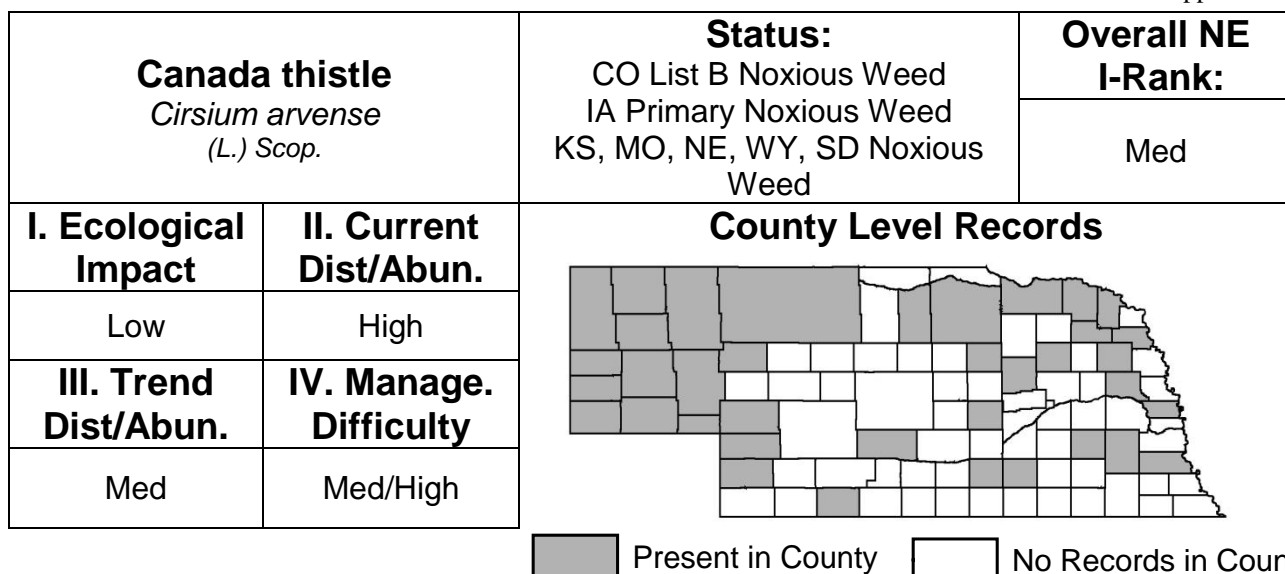


Comments:

This species is reported from the central and southern Great Plains, mostly on roadsides, waste ground, lawns, pastures, and meadows; it does not survive under cultivation (Stubbendieck et al. 2003). It occurs over most of Nebraska in ruderal habitats in heavy to sandy soil. It is known to be harvested commercially in the panhandle. Notable Survey Comments: primarily a roadside weed of little concern; not found in native ecosystems as a rule. Long ago reached its full range in Neb. Mostly a weed of disturbed places, not of native ones; mainly in roadside plantings; This species seems to be confined to road sides / highly disturbed areas. In my experience it has little effect on biodiversity; limited to state highway ROW. Plant population is decreasing (PRIDE), roadside plantings reported (Platte Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

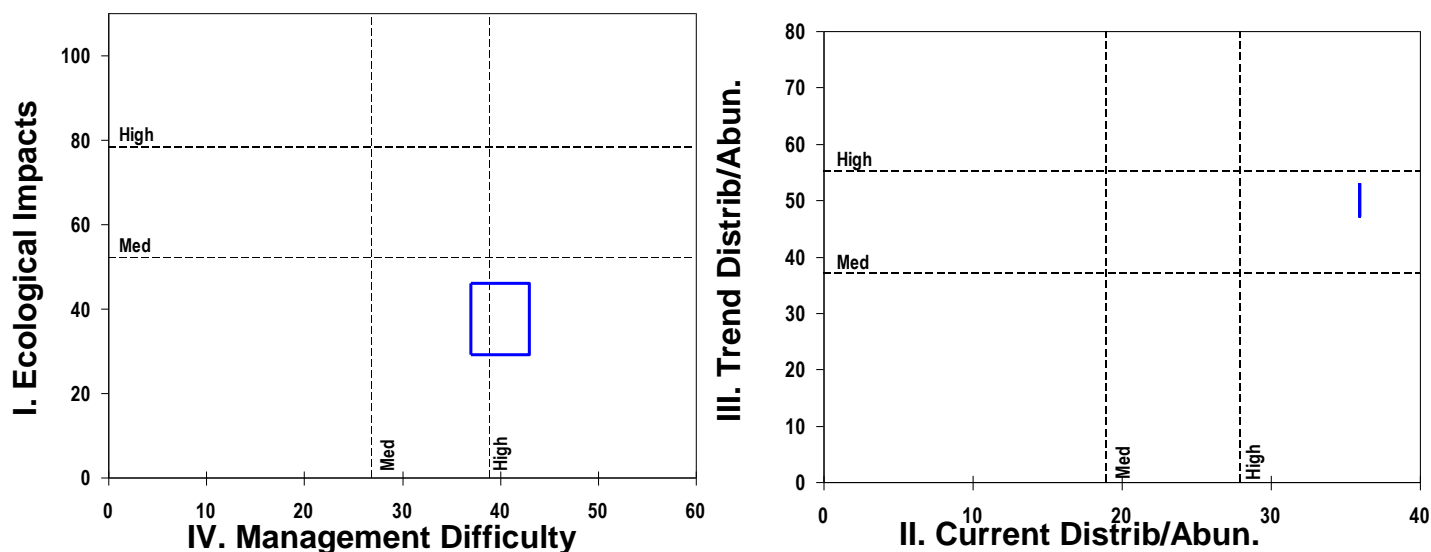


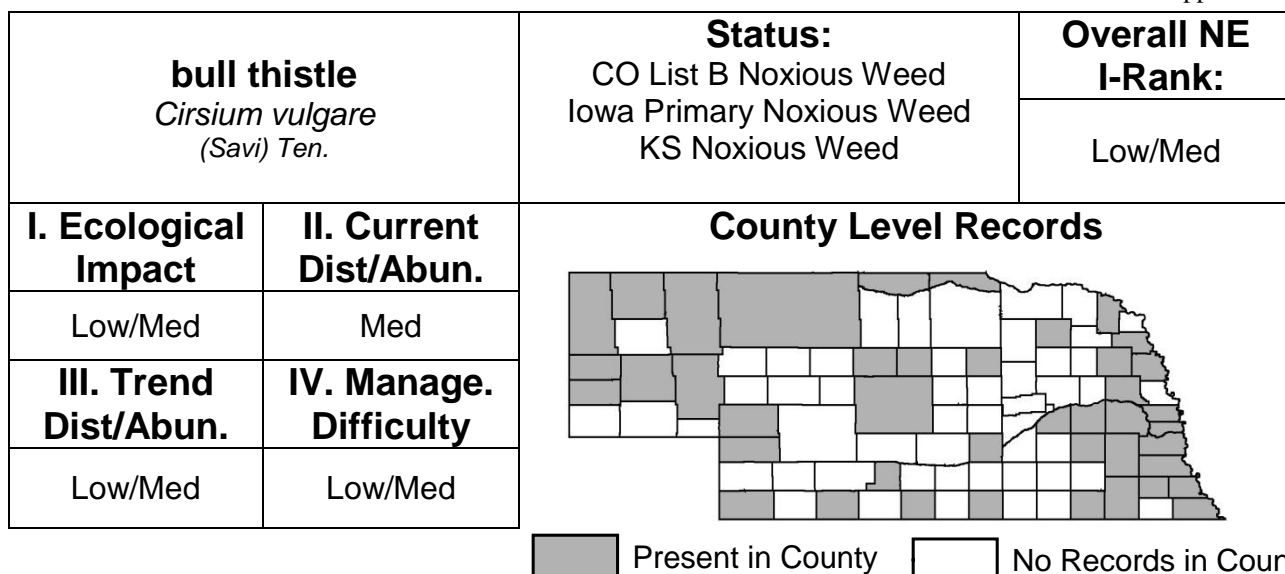


Comments:

This species is native to Asia, Africa, and Europe, (not Canada) and was collected in Nebraska by 1886 (Lancaster County). It was once considered a major weed in eastern Nebraska, but recently it is most troublesome in the western portions (Rolfmeier 2007). Within the Great Plains it occurs mostly in the central and northern portions, often in rangeland pastures, cropland, ditch banks, roadsides, mud flats, stream and lake banks, and disturbed sites, observed to be especially abundant in moist soil (Stubbendieck et al. 2003). Notable Survey Comments: A serious weed. Seems to have reached its full range long ago. Most abundant in western 1/2 of Neb; seems to be spreading along streams/rivers and reservoirs; Serious weed in wet meadows and on margins of other wetlands. Abundant in cropland, flood draws, riparian areas. Thrives on cultivation. If left unchecked it will form a monoculture. Spreads rapidly. Even with control measures Canada thistle will persist (PRIDE); It will need to be monitored closely to insure it does not get out of hand (M. Niobrara); found in riparian areas along Platte River and irrigation off tri-county canal system (Platte Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

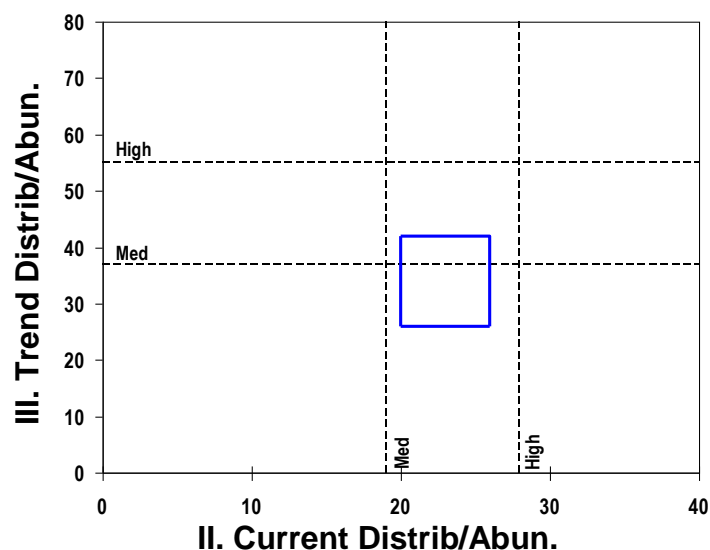
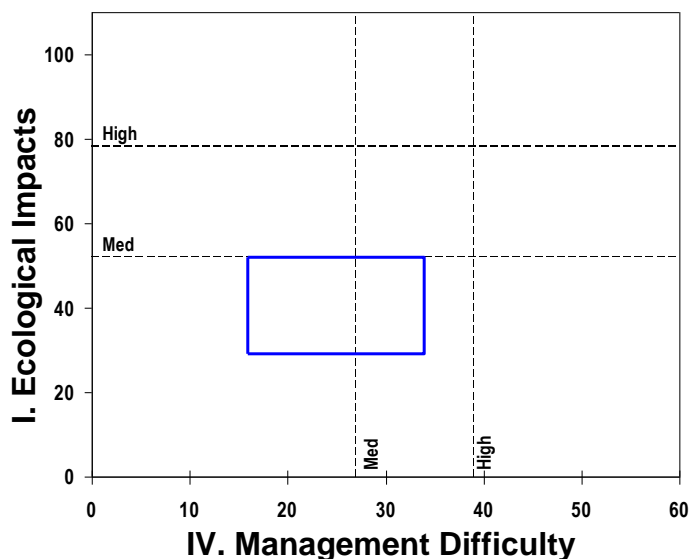


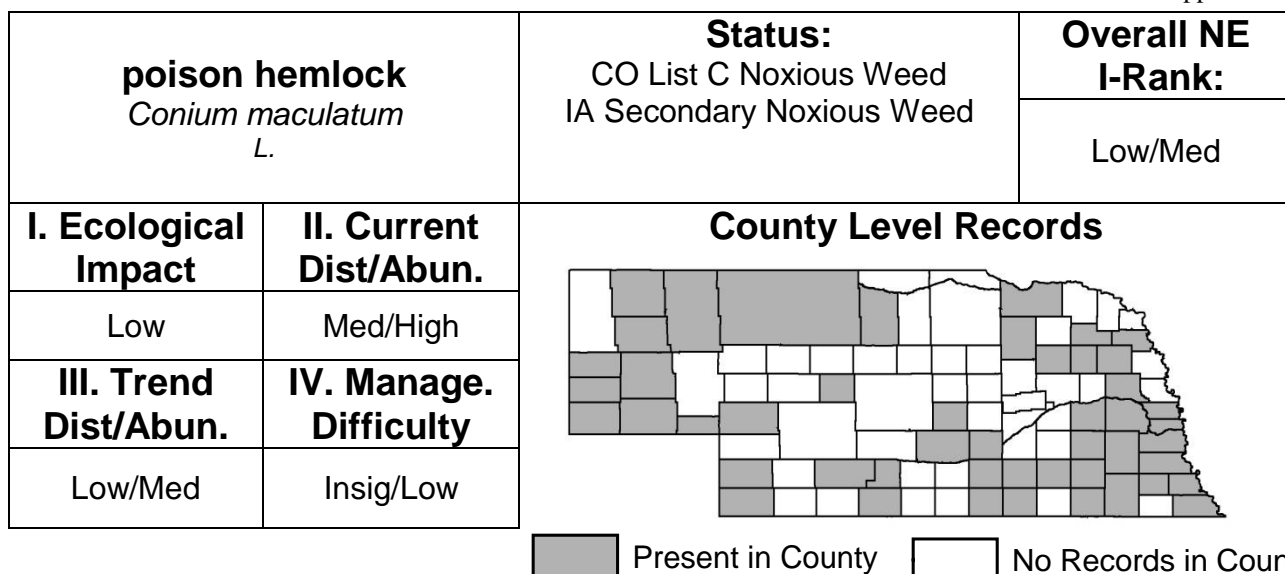


Comments:

This species is native to central, eastern and southern Europe, western Asia, and northern Africa, and was discovered in Nebraska by the 1890's (Rolfmeier 2007). The plant occurs throughout most of the Great Plains (excluding the southwest portions) in rangeland, pastures, meadows, old fields, gardens, and disturbed sites (Stubbendieck et al. 2003). Notable Survey Comments: long established and apparently only problematic in areas of heavy disturbance; sometimes abundant enough to be a problem, but often occurring as isolated individuals, apparently not spreading; plants seem fairly widespread but confined to highly disturbed areas and not apparently spreading to high quality habitats. My sense is that it is relatively stable (trend); very few infestations, but is dominant species around stock tanks, pivot heads, wells, etc. Seen in many habitats but insignificant (trend) due to management and control (PRIDE).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

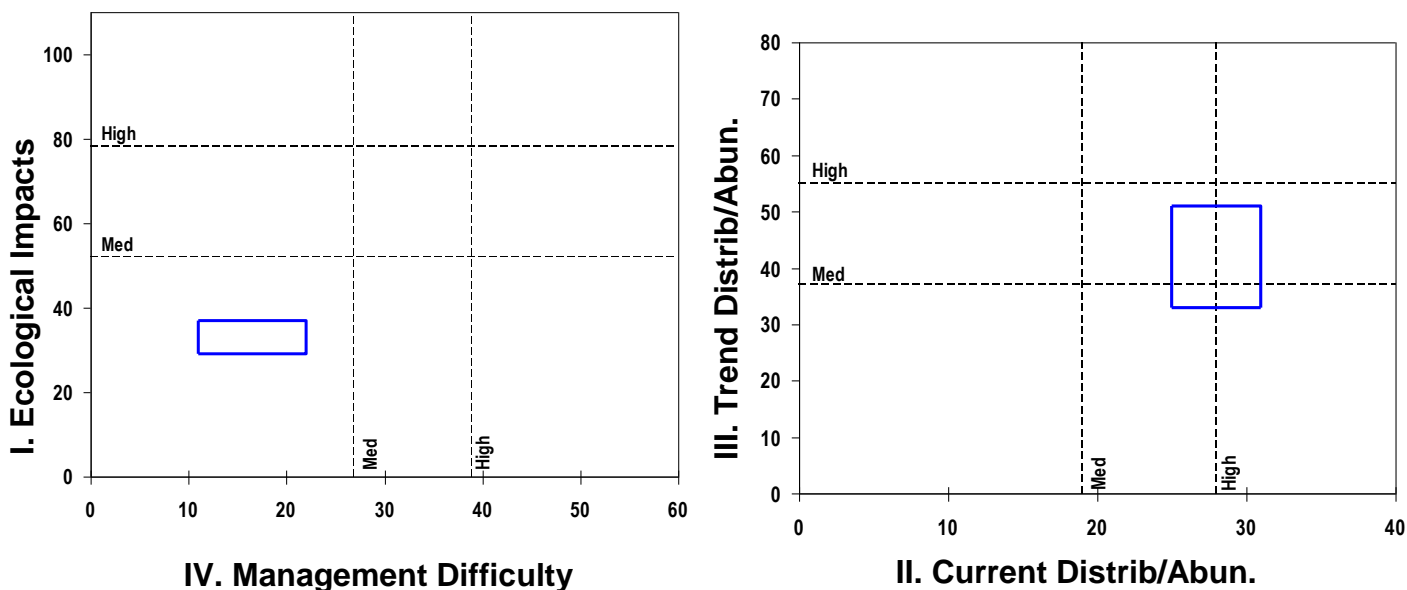


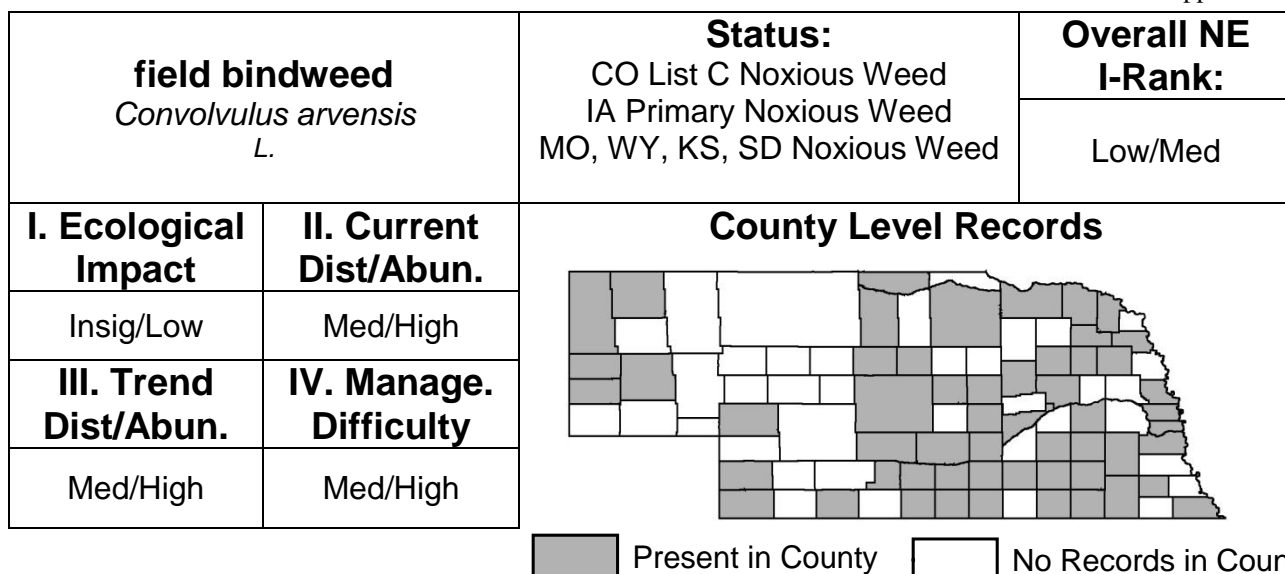


Comments:

This species is native to Europe, western Asia and North Africa, was first documented in Nebraska in 1936, and has been observed spreading rapidly since the 1960's (Rolfmeier 2007). It is known to occur throughout the Great Plains, being most common in the central and southeast portions (Stubbendieck et al. 2003). In Nebraska it usually occurs in disturbed, shaded, or open ground in parks, pastures, and along roadsides, where it has spread rapidly in the state in recent years. Because cattle usually avoid it as forage, it often increases under heavy grazing regime (Kaul et al. 2006). Notable Survey Comments: populations seems to fluctuate in response to local disturbance; seems to occur primarily in disturbed habitats. Appears to be expanding rapidly; Very invasive, appears to out-compete native vegetation. Doesn't seem to move to other riparian areas. In infested areas, the level increases/fluctuates with rainfall (PRIDE); it has been slowly increasing in population and crowding out some species, low lying areas and wetlands (Twin Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

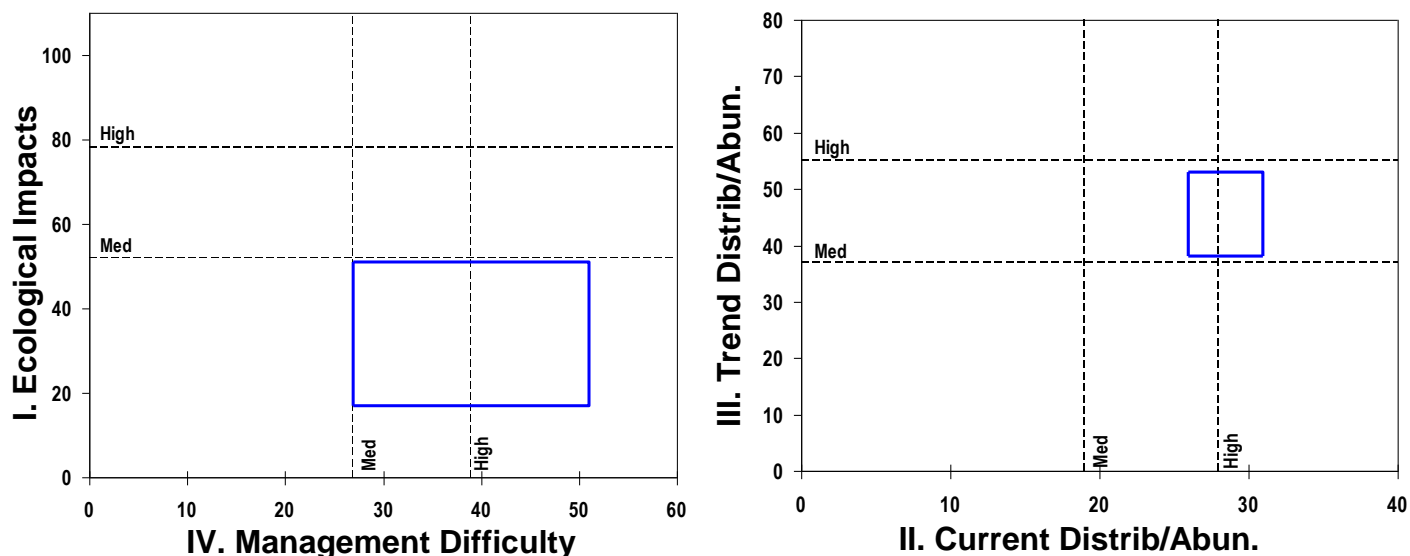


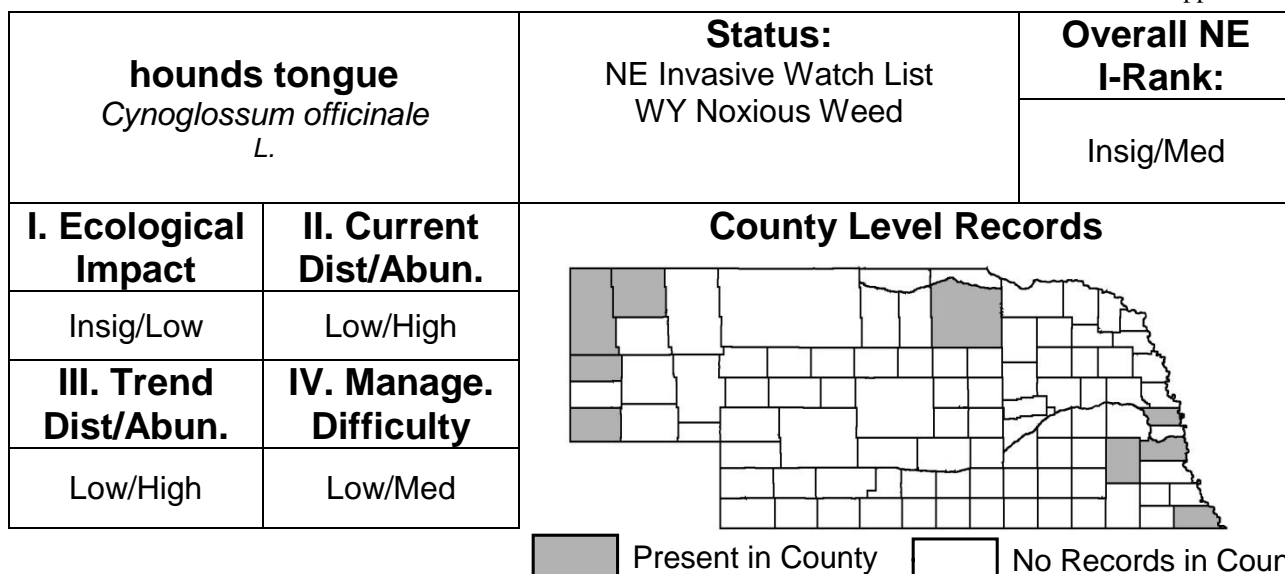


Comments:

This plant occurs throughout the Great Plains, most commonly in grain fields, waste places, gardens, and roadsides. It is perceived as a serious weed which is difficult to eradicate due to deep rhizomes, to a depth of 10 m (Stubbendieck et al. 2003). It occurs throughout Nebraska, infesting wheat fields in particular (Kaul et al. 2006). Notable Survey Comments: mostly restricted to anthropomorphic habitats, little impact on biodiversity; has long ago spread to all parts of Neb; if present has large impact. Cropland, Rows, homes, not a rangeland problem. Has taken advantage of the drought (PRIDE).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

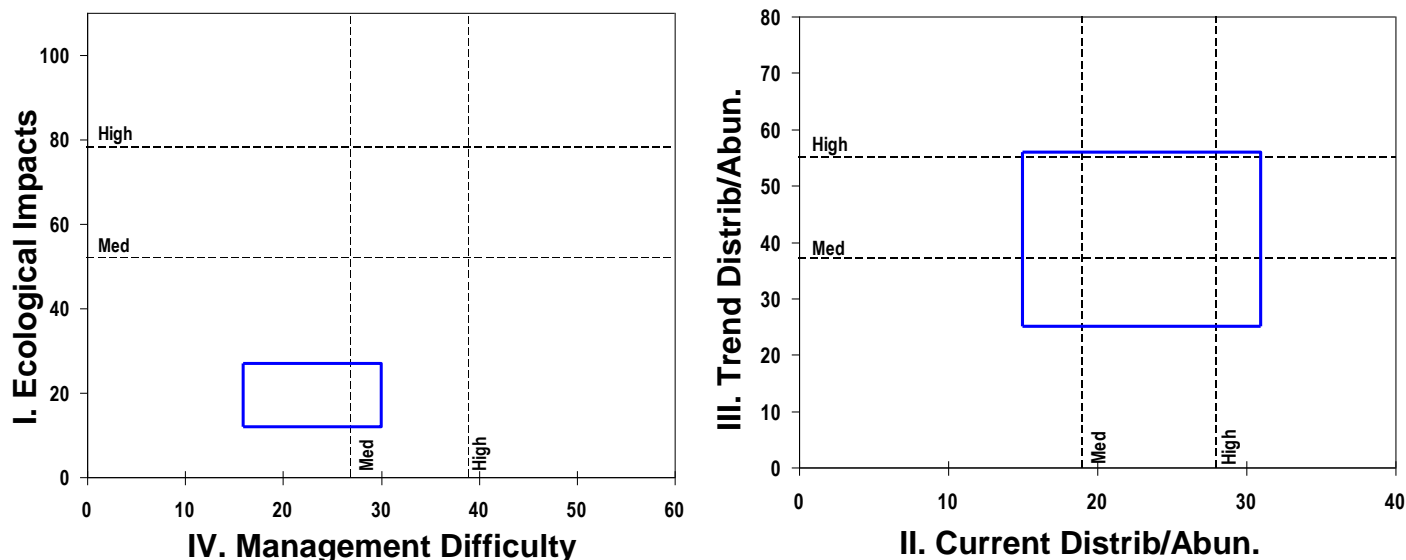


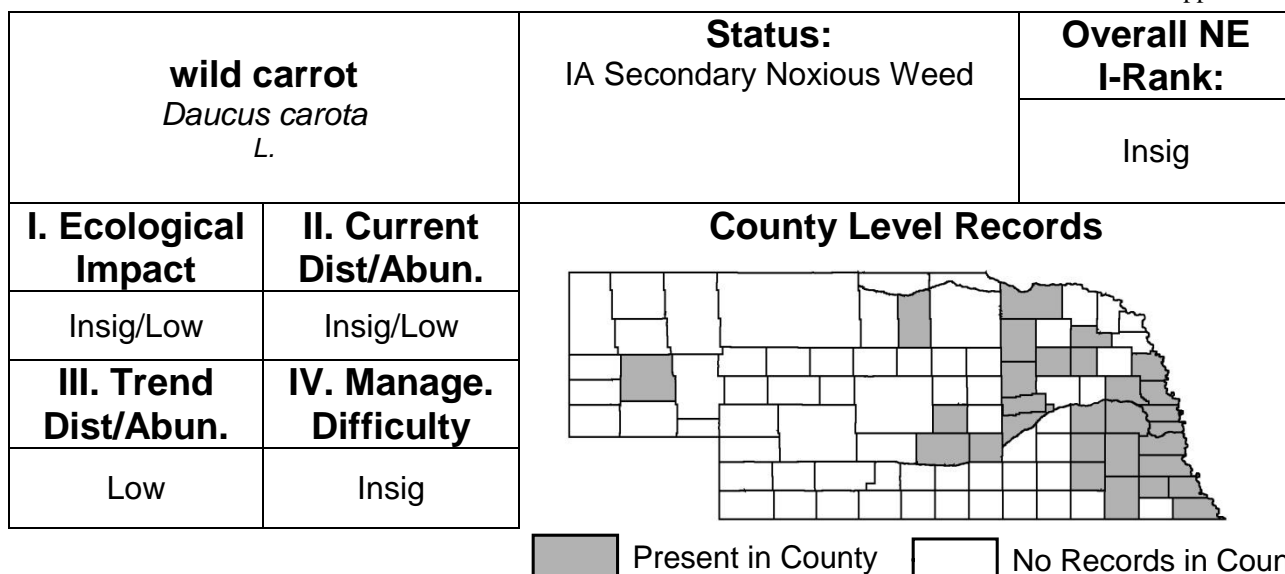


Comments:

This species is native from Denmark to Siberia, south to Spain, France and Iran. It was documented in eastern Nebraska by 1878. It generally doesn't out-compete grasses, but recent observations in the Pine Ridge indicates it is invading high quality forested habitats (Rolfmeier 2007). It has a diffuse distribution throughout the Great Plains (except for the southwest portions), mostly along roadsides, woodland edges, waste areas, and disturbed sites (Stubbendieck et al. 2003). In Nebraska it is uncommon, but locally abundant and increasing in the panhandle (Kaul et al. 2006). Notable Survey Comments: Mostly restricted to Pine Ridge where it is expanding; my experience is that this species is generally confined to heavily disturbed (grazed) areas where biodiversity has already been significantly impacted; Very invasive, spreads rapidly, toxic to horses. Expanding Aggressive and invasive in wooded or riparian areas. Seed structure conducive to spread. Patches get more dense and expand (PRIDE); riparian zone along Platte in low quality pasture or waste areas (Platte Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

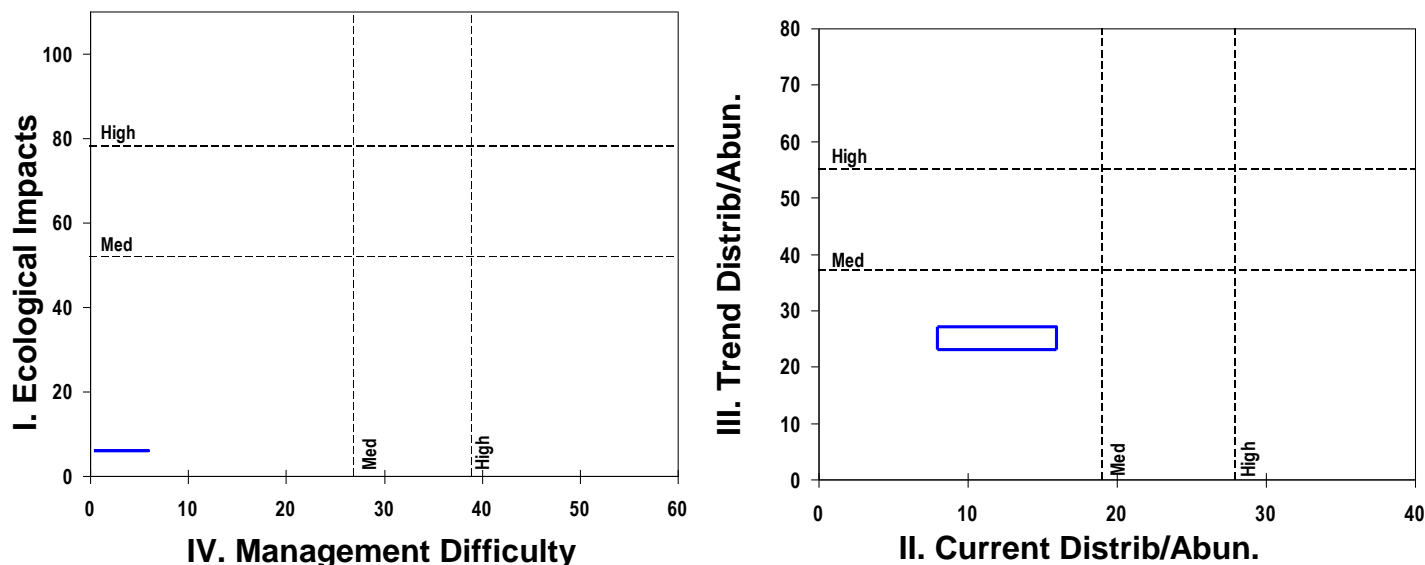


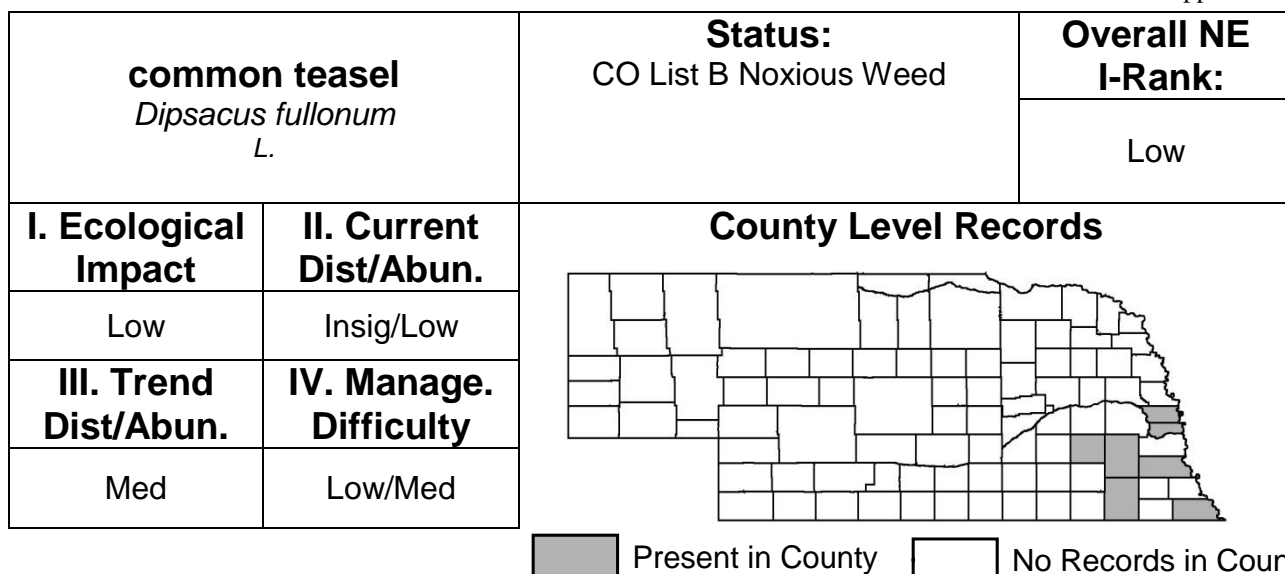


Comments:

This species primarily occurs in the eastern half of the Great Plains in pastures, meadows, roadsides, and woodland openings/edges, rarely in cultivated fields (Stubbendieck et al. 2003). In Nebraska it is mostly known from the eastern half of the state, but has been collected in the Panhandle (Kaul et al. 2006). Notable Survey Comments: seems fairly stable and mostly localized in areas of high disturbance. Overall range has increased but many populations seem not to persist; seldom abundant enough to be a problem. A very bad weed in Eastern States, but not in Neb; Roadsides mainly; mainly in degraded areas as far as I know. Bigger problem east of Neb; generally in disturbed areas. My sense is that it pretty much occupies suitable habitats range wide.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

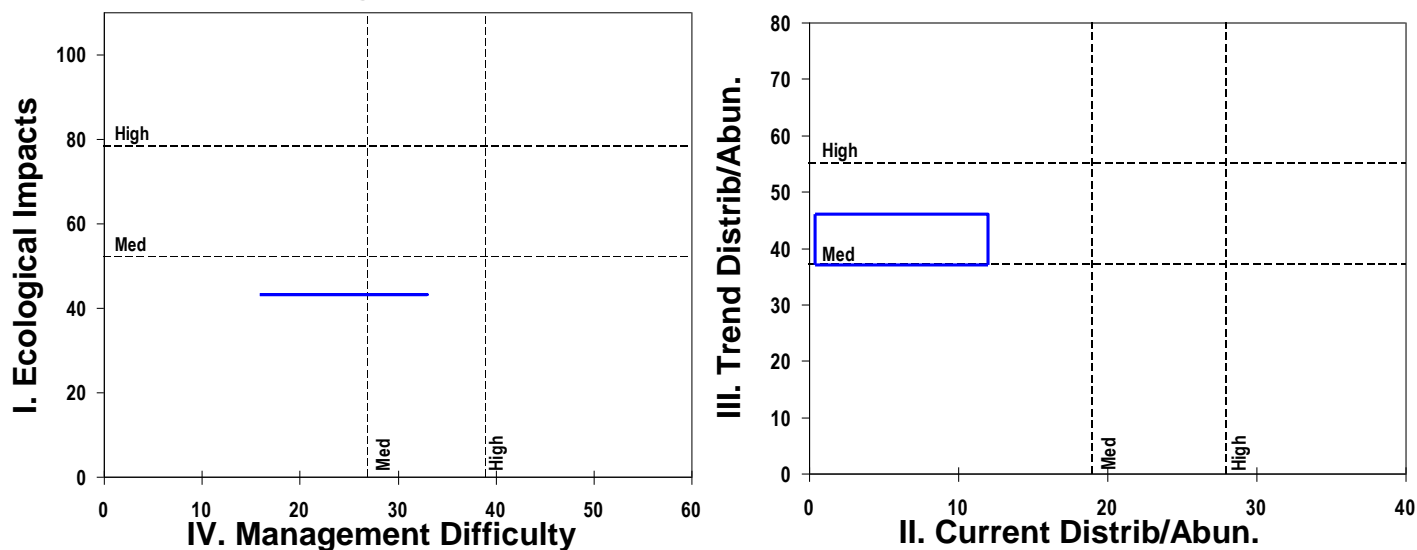


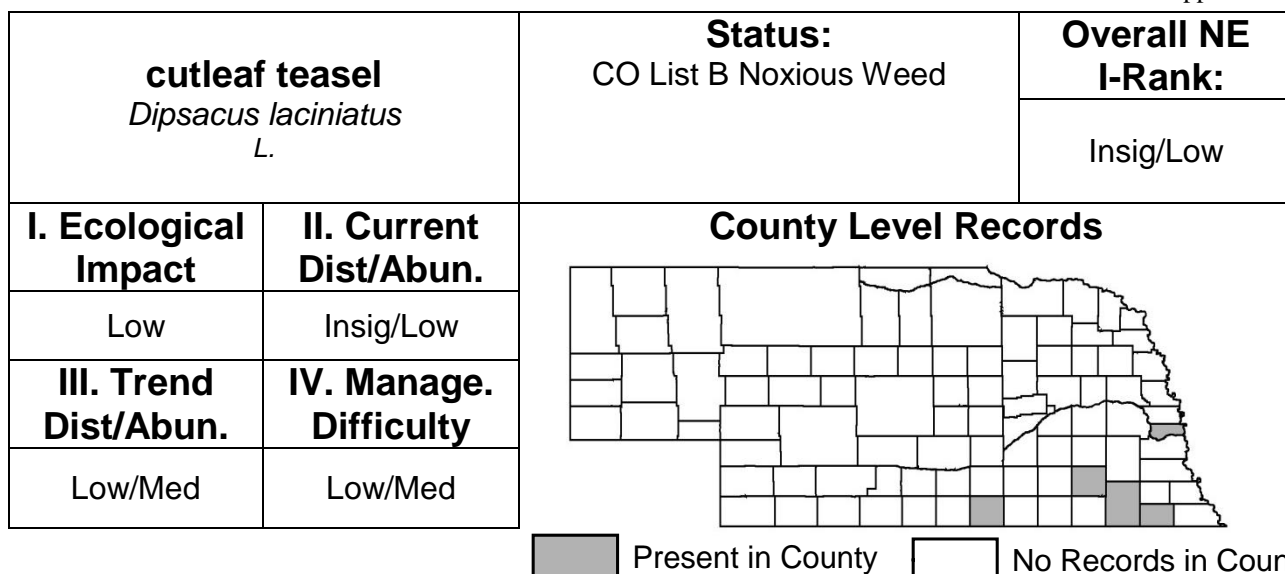


Comments:

This species is native to temperate Asia, northern Africa and Europe, and was first collected in Nebraska in 1974 in Richardson County (Rolfmeier 2007). Although a problem in Kansas and Wyoming, shows no signs of being a pest in Nebraska (Kaul et al. 2006). Notable Survey Comments: apparently not long persistent; not common enough to be a problem. Could become serious in SE counties; we don't think it will be a big problem. Seems limited to disturbed areas; rare in Neb.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

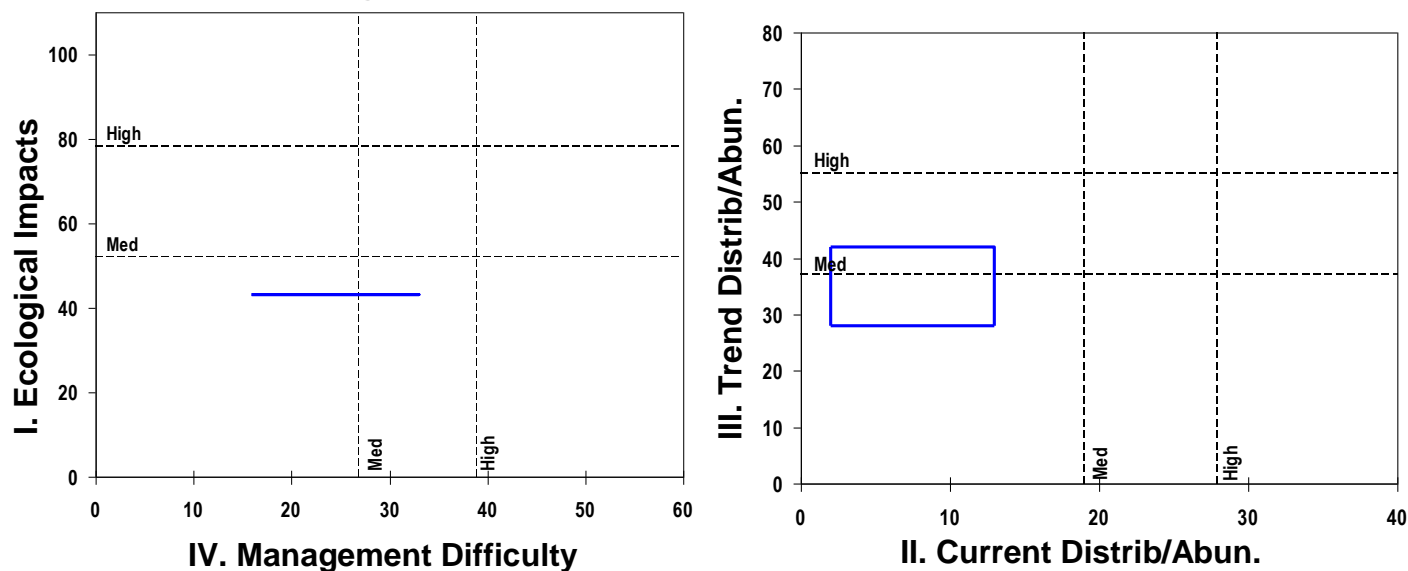


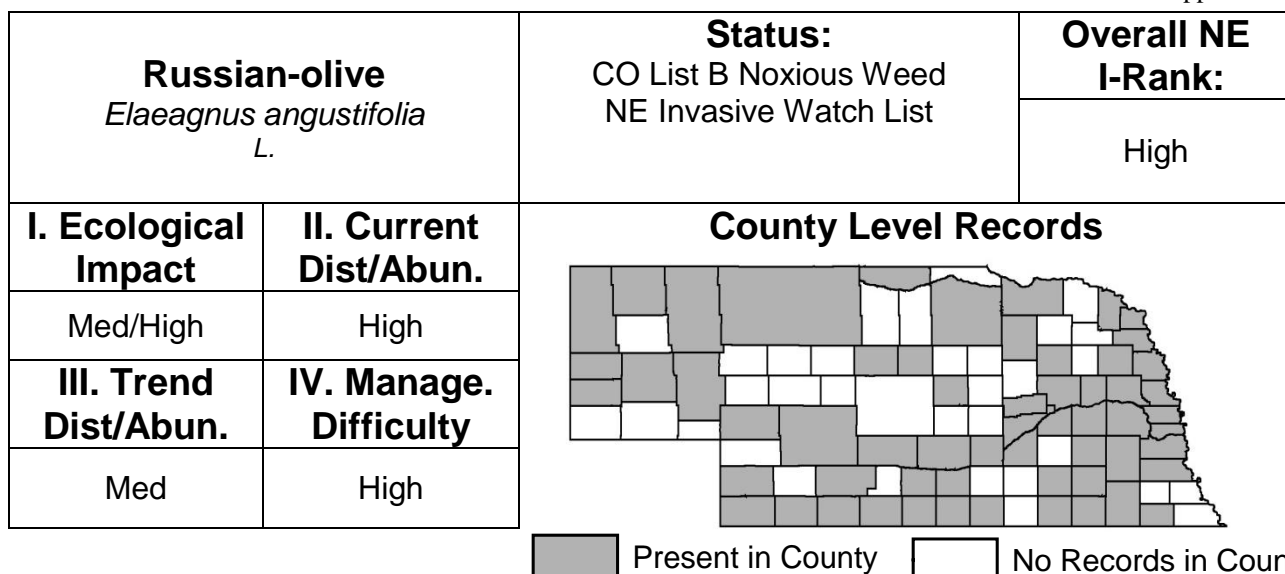


Comments:

This plant is native to Europe and temperate Asia, and was first noted in Nebraska in the 1970's (Sarpy County). It has been rapidly spreading recent years, and can invade mesic native habitats. It mostly known from roadsides in Nebraska (Rolfsmeier 2007). Notable Survey Comments: apparently only starting to spread away from roadsides. Starting to spread noticeably since the 1980s; Known only in a few places. Seems not to be increasing very fast; small patches I have observed on Highways near Lewiston in Pawnee Co appear to be increasing in size.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

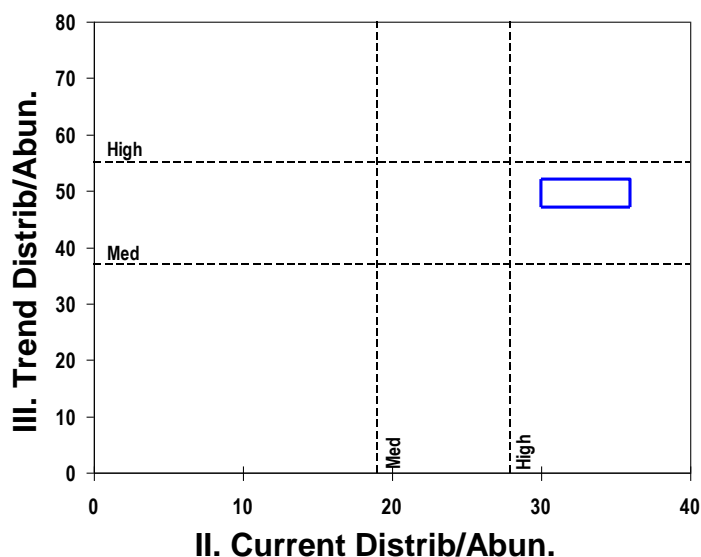
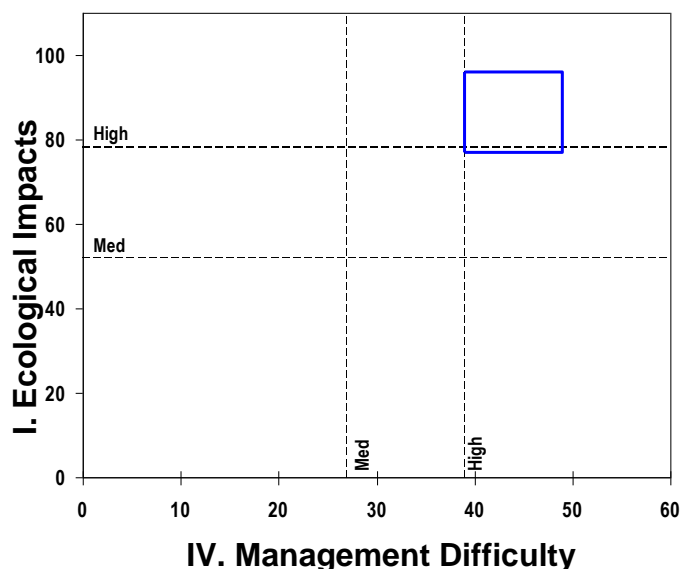


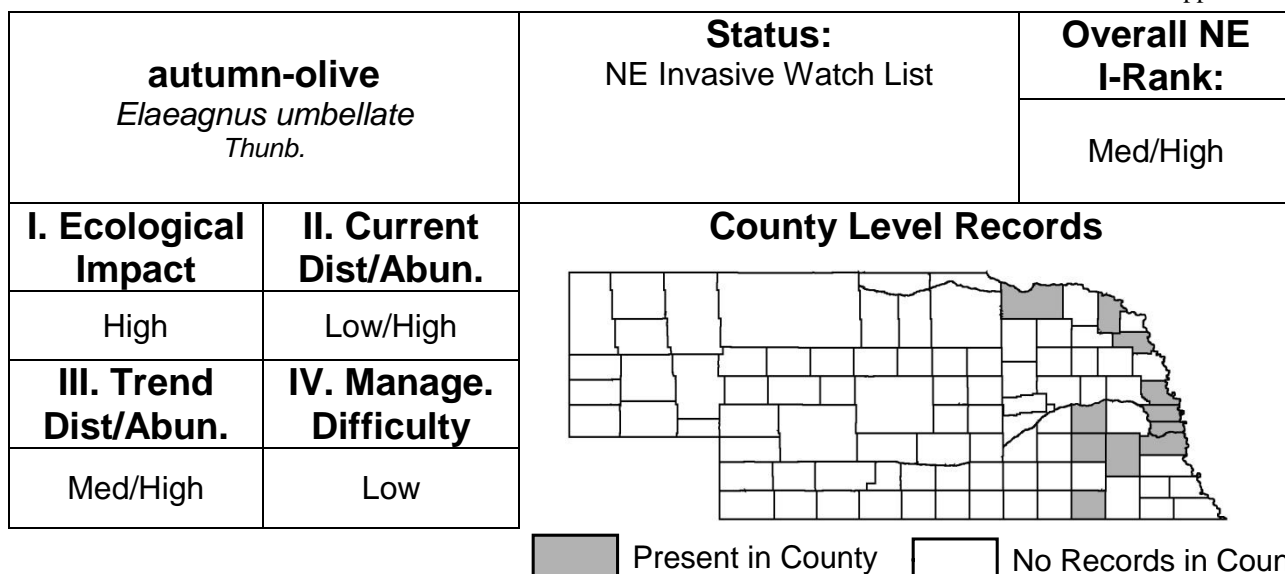


Comments:

This species is native to southeastern Europe and western Asia, and was first introduced in Nebraska in the 1880's. It is problematic in the western 1/3 of the state, especially along the Platte River (Rolfmeier 2007). It occurs throughout the Great Plains, being most common in the western portions and being most abundant along rivers and stream understory locations (Stubbendieck et al. 2003). Kaul et al. (2006) note it is especially a nuisance in sandy river valleys. Notable Survey Comments: affected with disease and seems to be decreasing; Serious problem in river valleys and meadows. Shades out herbaceous layer; Invasive in riparian areas. Stays in riparian, gets more dense, but does not seem to spread upland, existing infestations increasing (PRIDE), this plant has been noted to the west of the MNWAG boundary (M. Niobrara), Riparian zones along Platte, the density increases the further west you go Buffalo/Dawson/Lincoln Counties (Platte Valley), populations are increasing in Republican River Valley and adjacent tributaries (Twin Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

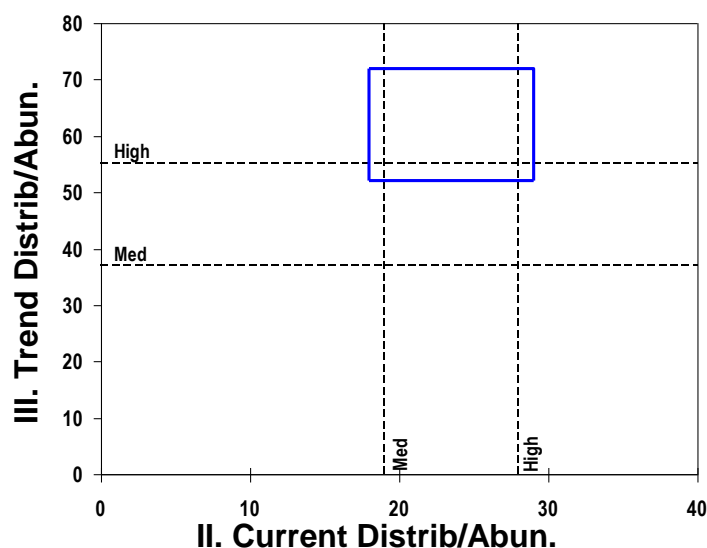
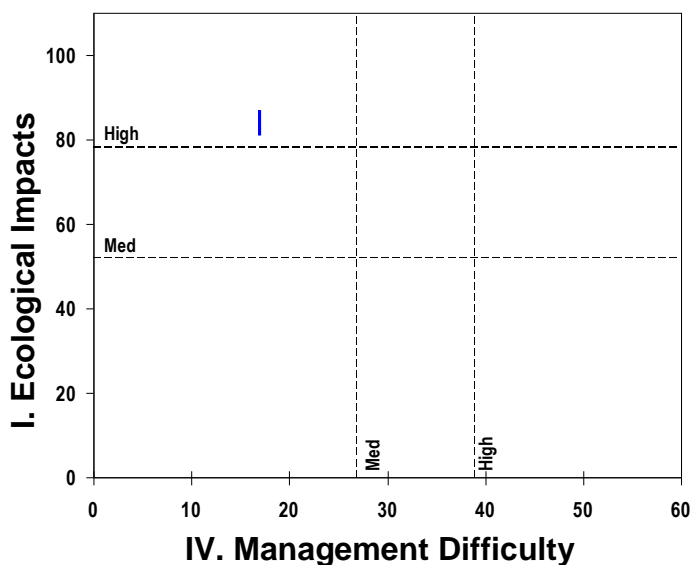


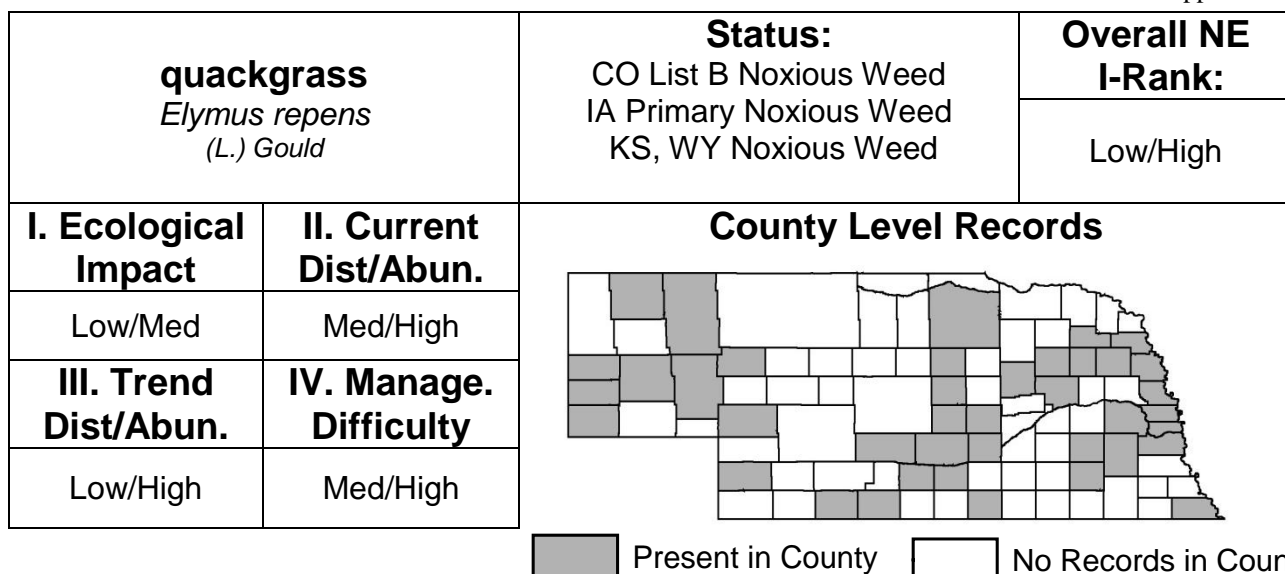


Comments:

This species is native to Asia and was first noticed outside of cultivation in the 1980's. It can sometimes out-compete native species in riparian areas, and is readily dispersed by birds (Rolfmeier 2007). Occurs in mesic to dry soils in Nebraska, mostly in southeast counties where it is spreading rapidly (Kaul et al. 2006). Notable Survey Comments: can become superabundant once established; Becoming a problem in Eastern NE, increasing/spreading rapidly.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

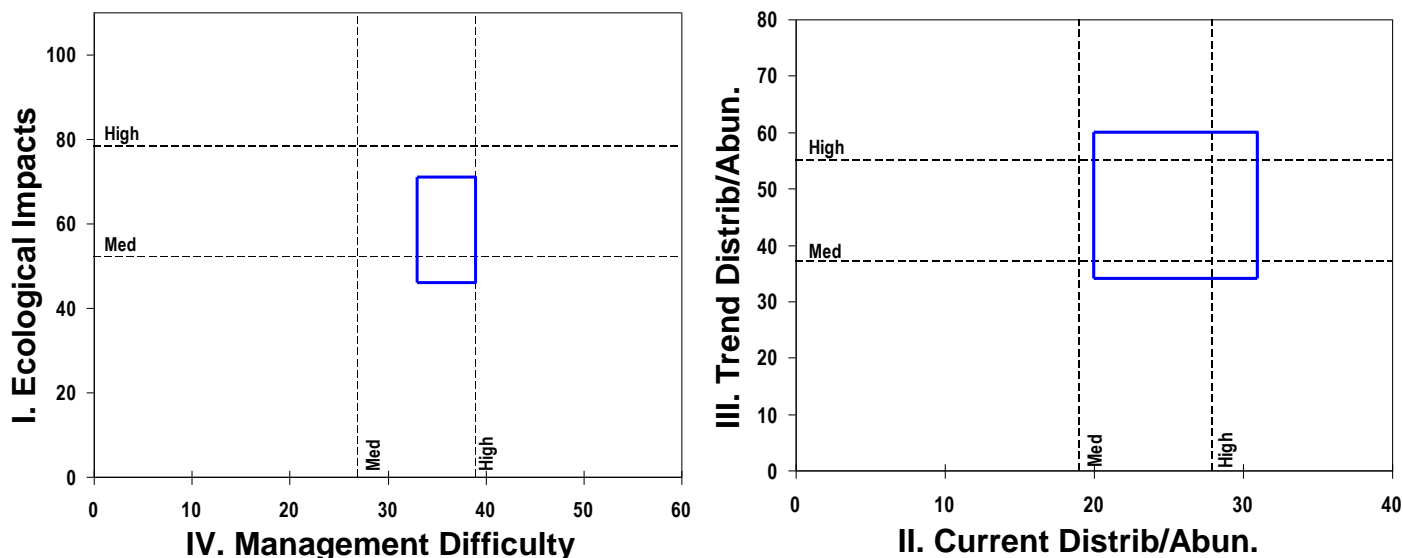


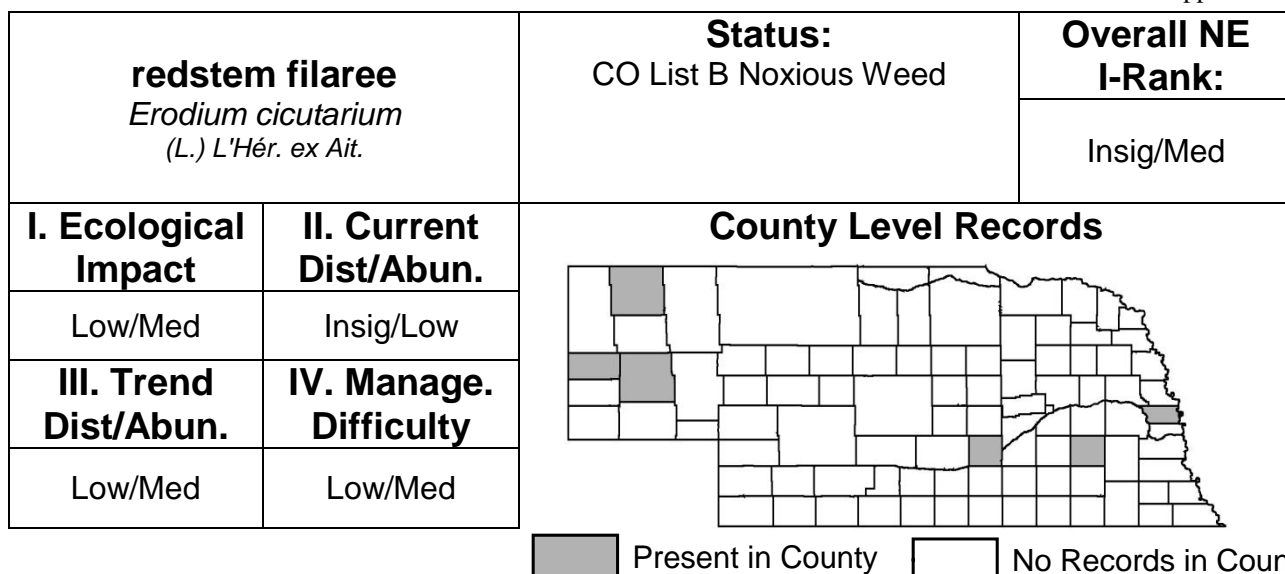


Comments:

This grass is native to temperate Europe and central Asia, and was first documented in Nebraska in Lancaster County in 1905 (Rolfmeier 2007). It occurs mostly in the central and northern portions of the Great Plains, usually in moist areas of pastures, lawns, gardens, meadows, roadsides, ditches, and cultivated fields. It is perceived as an aggressive weed that out-competes more desirable plants (Stubbendieck et al. 2003). It occurs throughout most of Nebraska but seemingly uncommon or absent in Sandhills (Kaul et al. 2006). Notable Survey Comments: more common in the north and abundant locally- but appears not to be increasing rapidly; Does not appear to be an aggressive invader in Neb. Not nearly as bad as smooth brome (trend). I don't see it invading new areas that I have visited.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

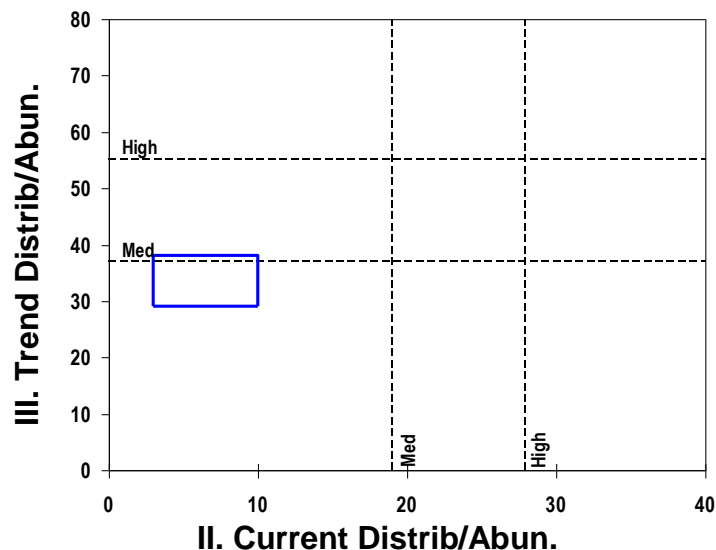
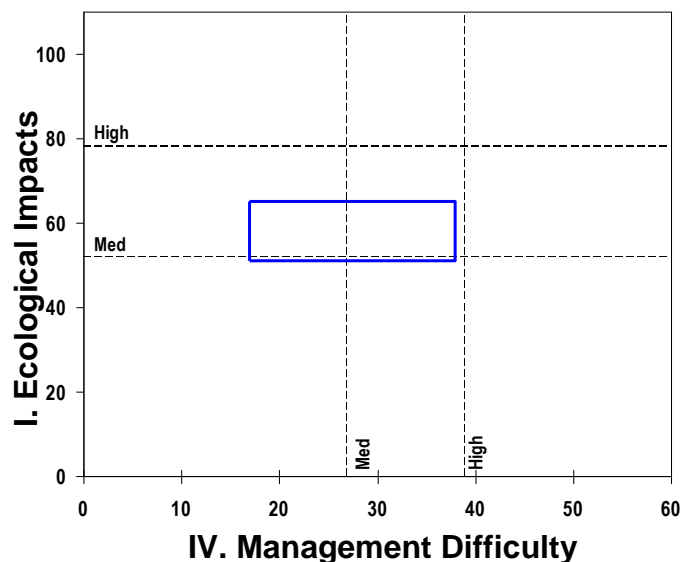


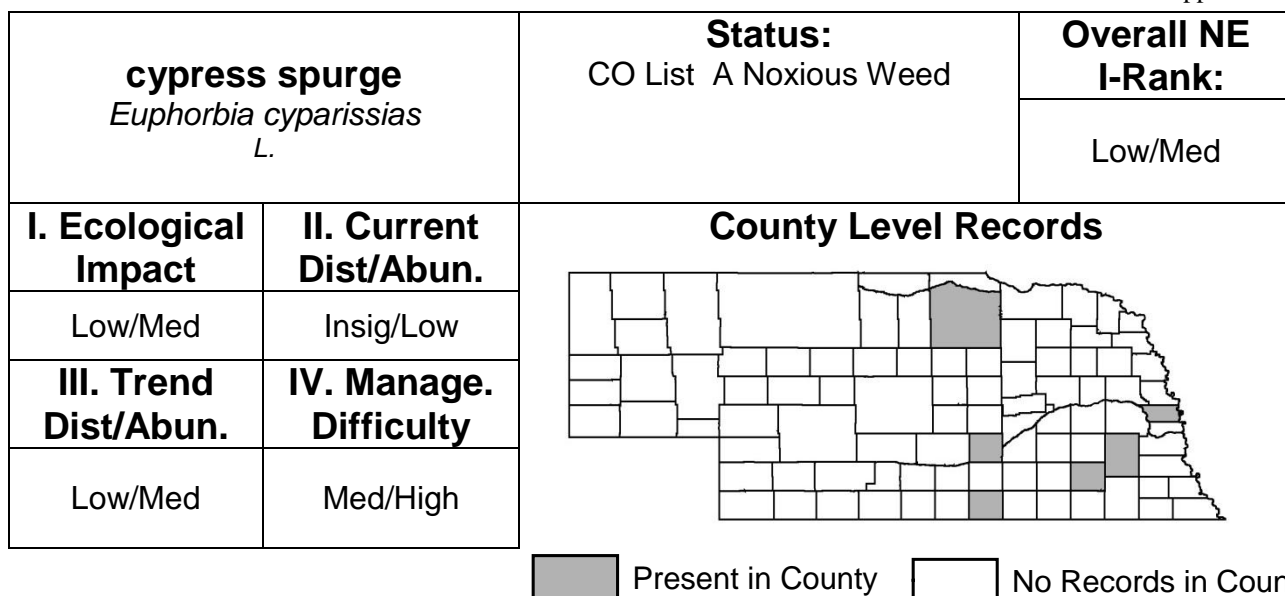


Comments:

This Eurasian plant occurs mostly in waste places and overgrazed pastures on dry or well-drained soils. It is not common in Nebraska (Kaul et al. 2006). Notable Survey Comments: range expansion tied to regular disturbance- not likely to occur in high quality sites; not common at any site known to us.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

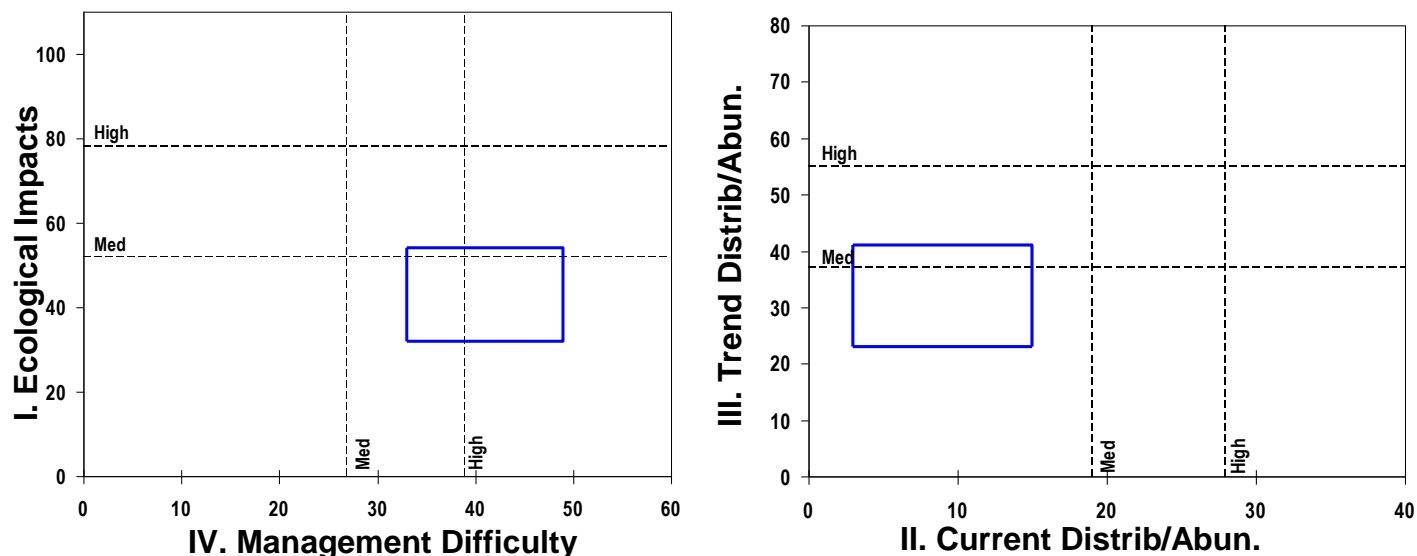


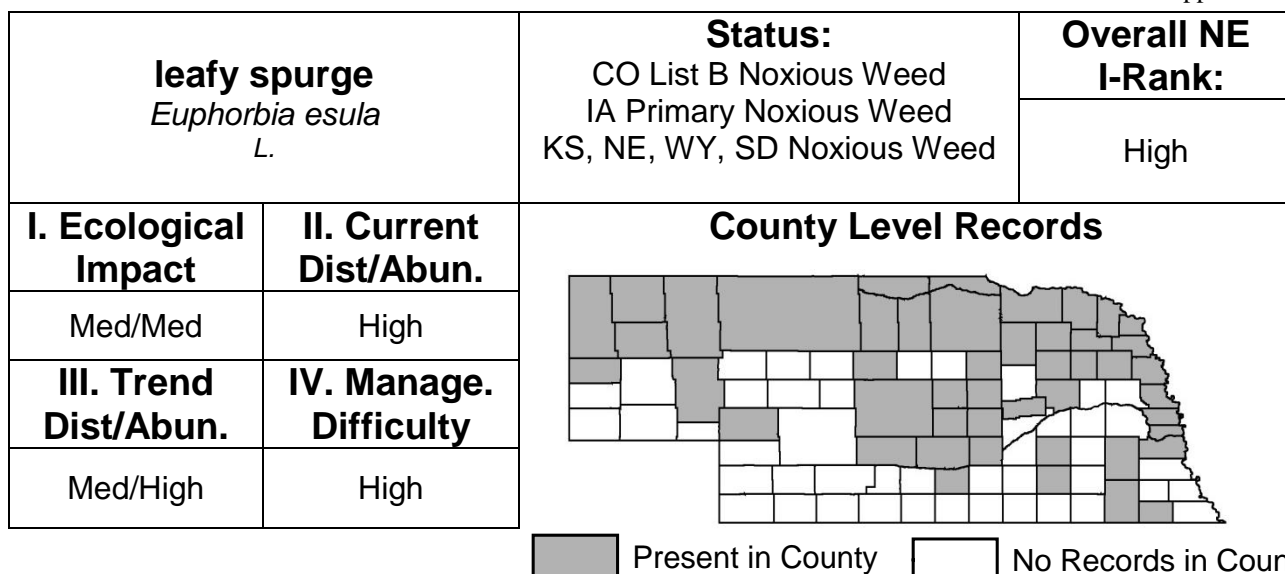


Comments:

Introduced from Europe, this plant species now has a scattered distribution in the eastern half of the Great Plains (Stubbendieck et al. 2003). This escaped ornamental was first collected in Nebraska in 1878 in Douglas County (Kaul et al. 2006). Notable Survey Comments: apparently not persisting long in the wild; a rare plant in Nebraska.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

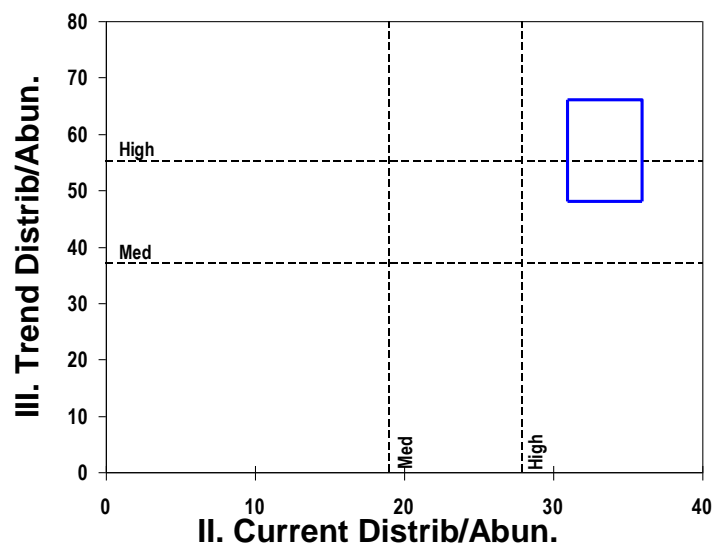
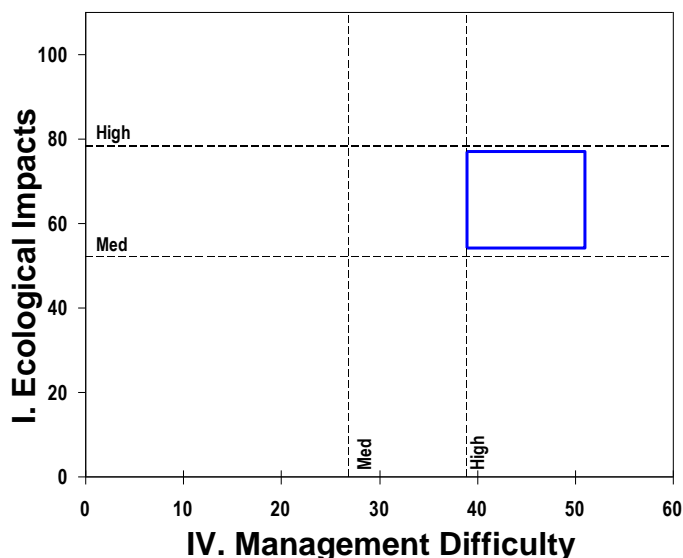


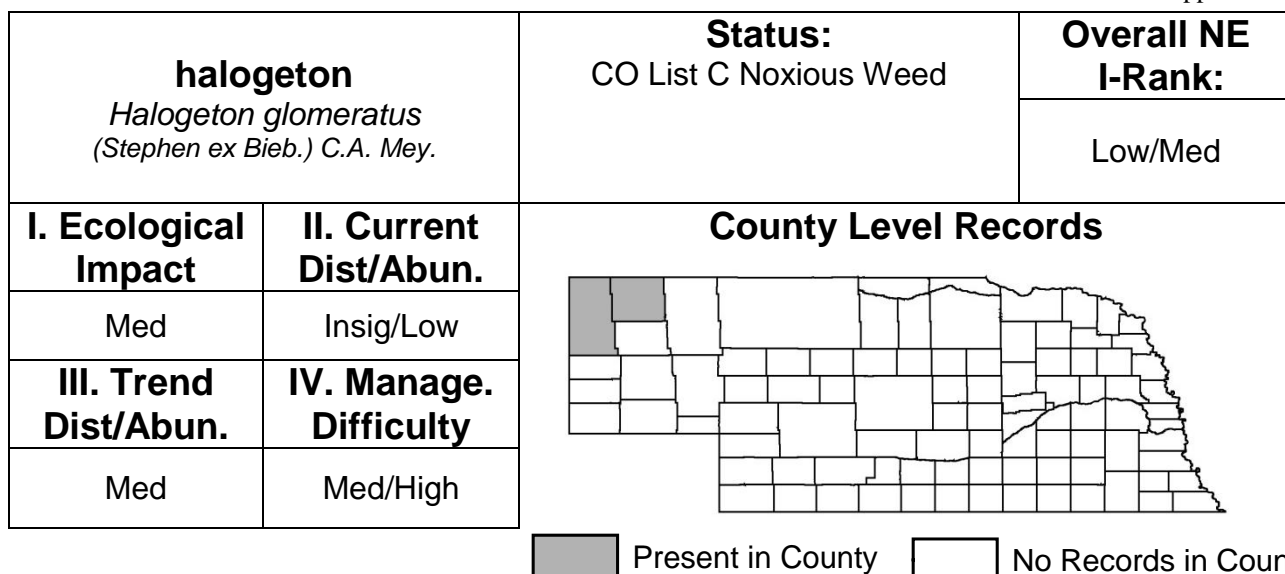


Comments:

This species is native to Eurasia, and was first collected in Nebraska in 1929, being observed as problematic in Cherry County by the 1950's (Rolfmeier 2007). It occurs in the northern and central Great Plains, often infesting irrigation ditch banks, roadsides, fields, woodlands, shelter belts, disturbed sites, rangeland, and especially sub-irrigated meadows (Stubbendieck et al. 2003). In Nebraska it occurs statewide, except at the borders of Sandhills. It is known to be difficult to eradicate (Kaul et al. 2006). Notable Survey Comments: has increased in range and abundance in recent years; Increasing to west and south. Occurs in several panhandle counties; Serious range weed. Hear more ranchers complain about this than anything else; Invasive and aggressive. Spread by wildlife and birds, seeds, roots, rhizomes. Integrated control measures effective, but persistence required (PRIDE); Increasing due to new discoveries in Riparian Zones- density of old stands in pastures showing decline due to treatment and biocontrol (Platte Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

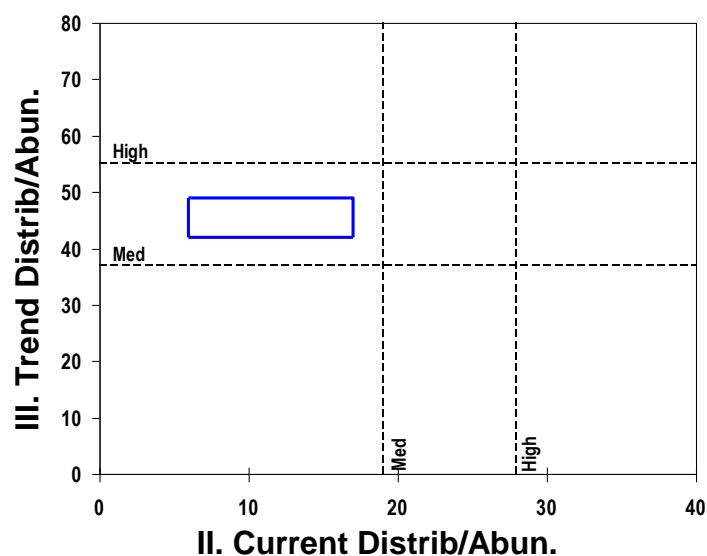
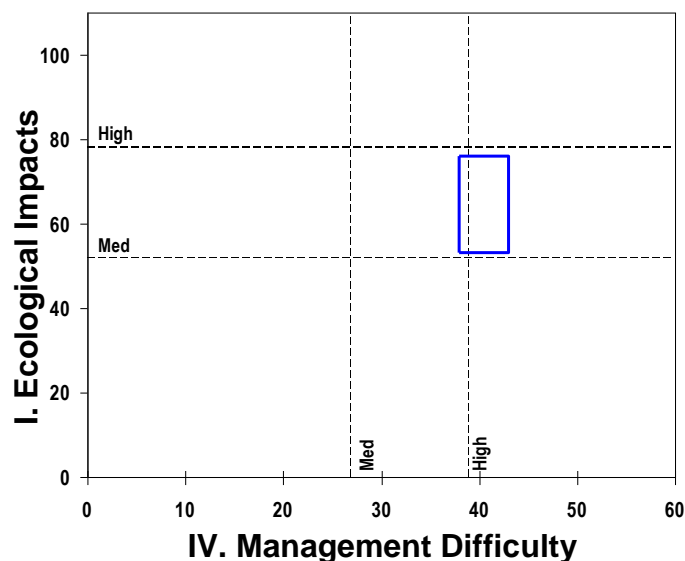


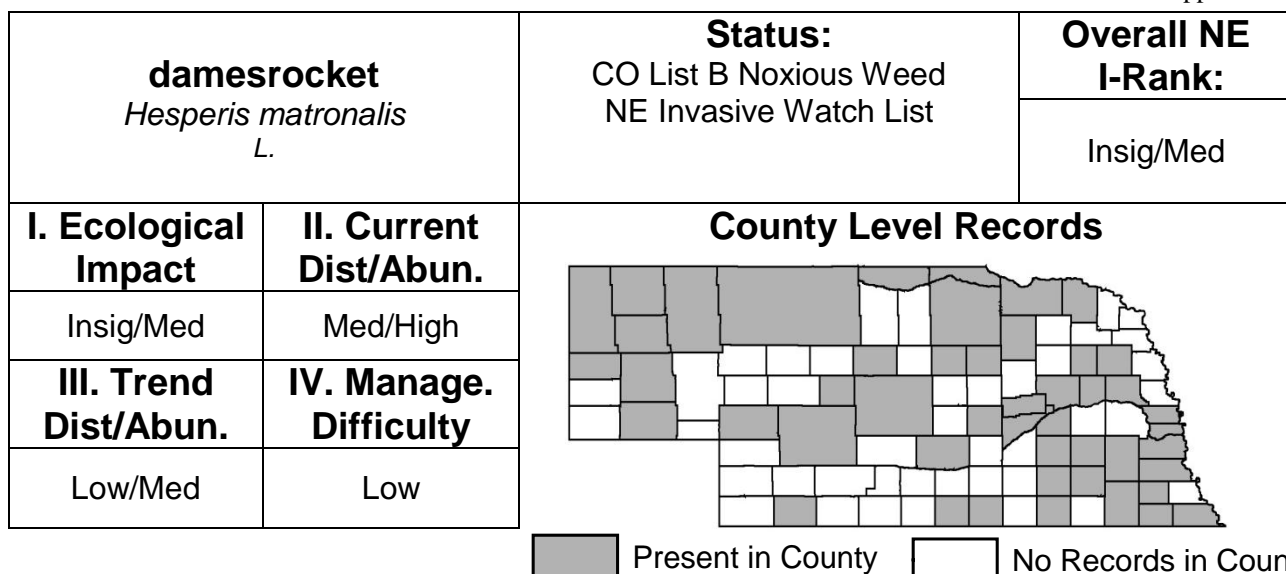


Comments:

This species is native to southeastern Russia and northwestern China, and was first documented from Nebraska in 1995. Observations indicate that it is becoming abundant on badlands in portions of the Oglala National Grasslands (Rolfmeier 2007). It has been observed as locally abundant on bare clay and badlands, especially in Panhandle or saline habitats (Kaul et al. 2006). Notable Survey Comments: Where it occurs it has recently exploded, but is still restricted to a small, but rapidly expanding area; Only locally a problem, but potentially widespread, very bad weed W of Neb; only a few populations in Neb.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

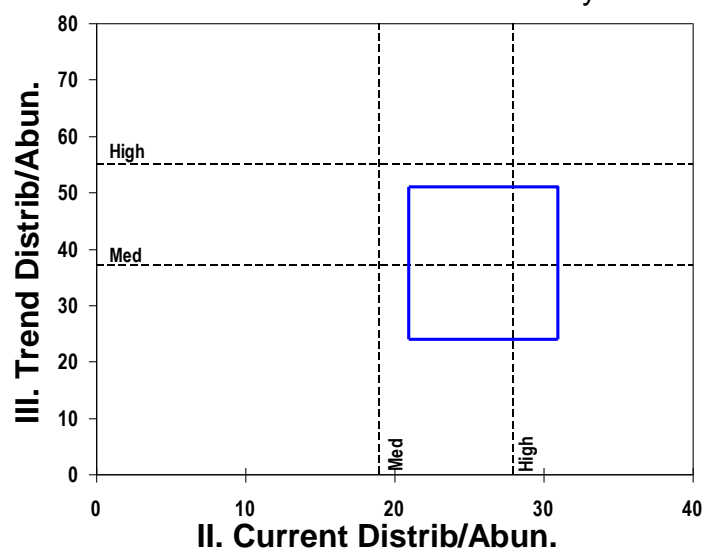
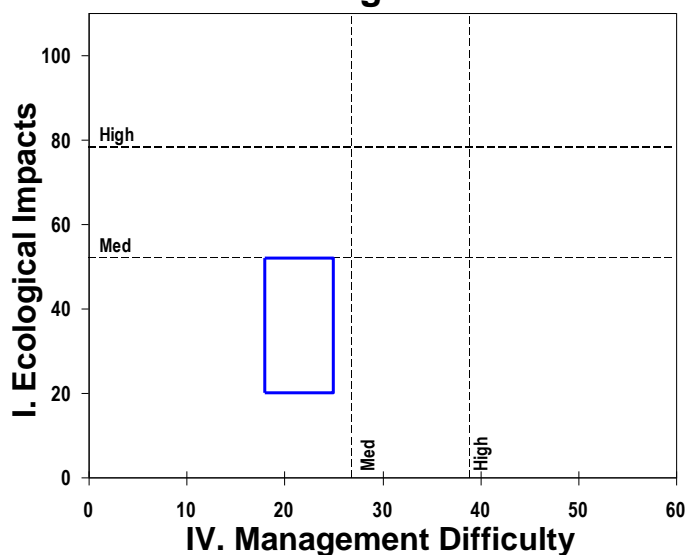


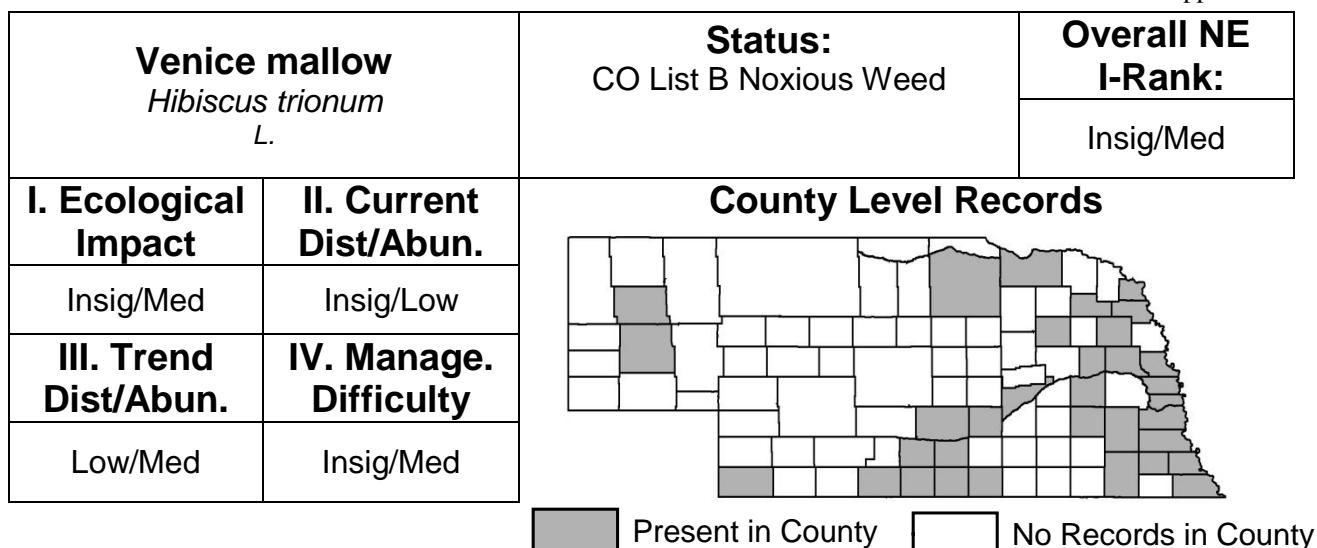


Comments:

This species is native to temperate Asia and central and southern Europe, and was first collected in Nebraska in Saline County in 1887. The plant often becomes abundant in forested areas (Rolfmeier 2007). It occurs in the central and northern Great Plains regions along roadsides, waste areas, abandoned farm sites, and open woods (Stubbenieck et al. 2003). Observations in Nebraska indicate it occurs throughout most of Nebraska, but being rare or absent in Sandhills (Kaul et al. 2006). Notable Survey Comments: appears to be increasing and persisting in many woodlands; Increasing fast in the Panhandle; Does not out-compete native in Riparian areas. Doesn't appear to cause any problems (PRIDE); It does not spread here. Roadside seedings do not even persist (West Central); Roadside planting Dept. of Roads (Platte Valley); occurs primarily under trees in abandon farm sites or waste areas (Twin Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

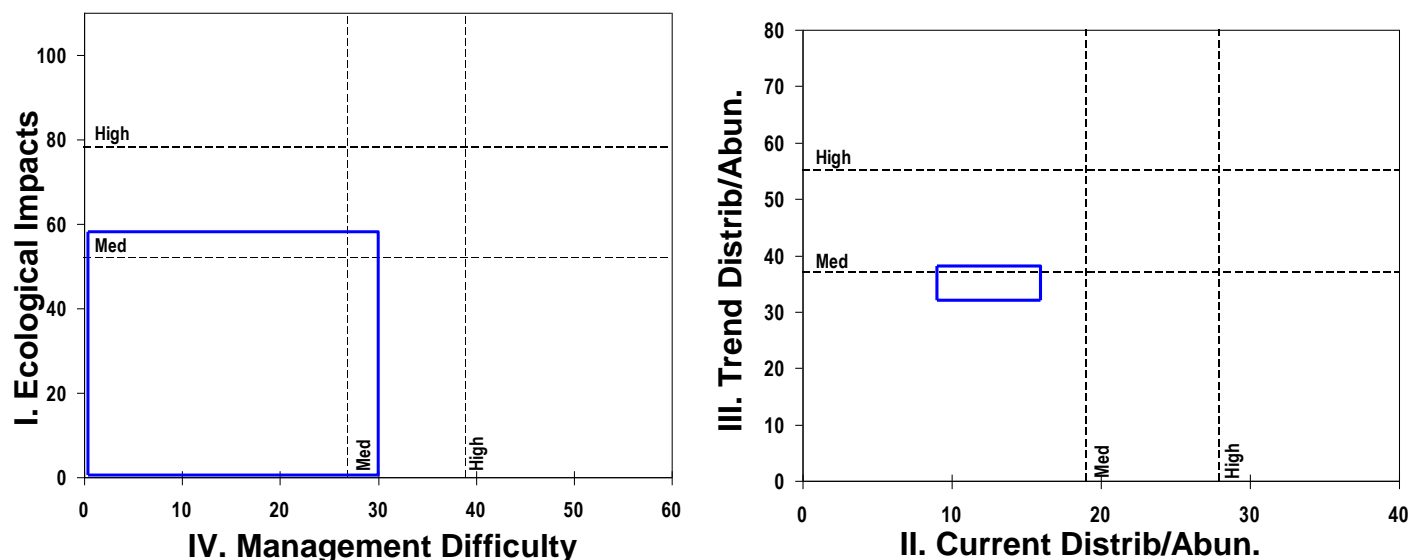


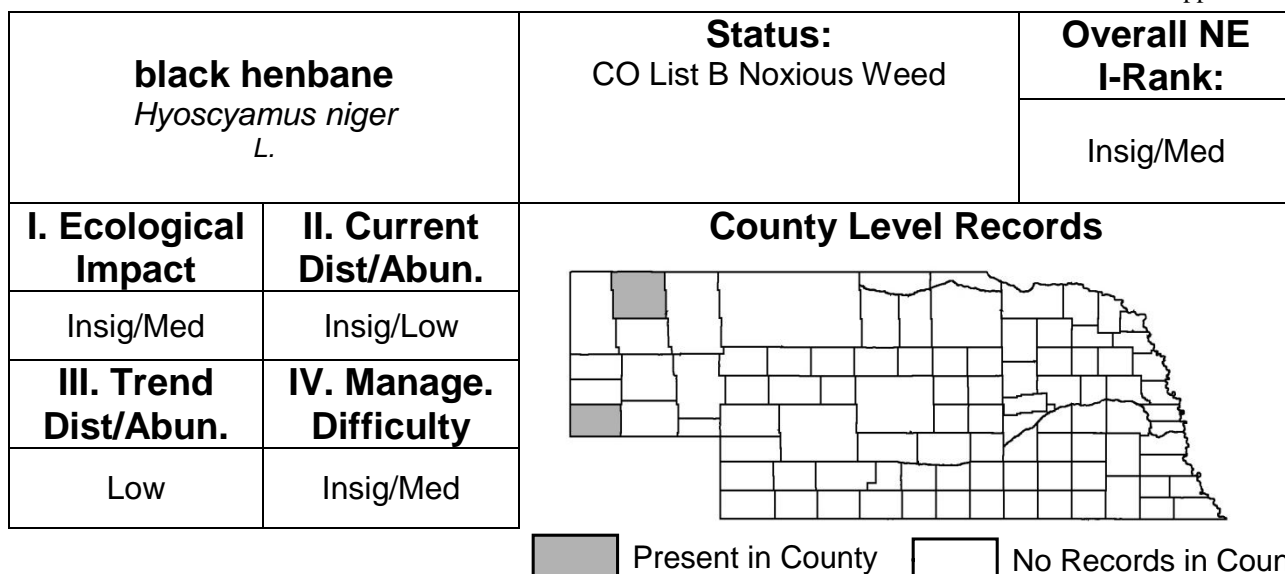


Comments:

This species is scattered throughout the Great Plains, being least common in western portion and most often occurring in gardens, cultivated fields, pastures, roadsides, along railroad corridors, and waste places (Stubbendieck et al. 2003). It occurs mostly in the eastern half of Nebraska but seems to be spreading west (Kaul et al. 2006). Notable Survey Comments: strictly an ag/roadside weed; weed of disturbed areas with little to no effect on biodiversity.

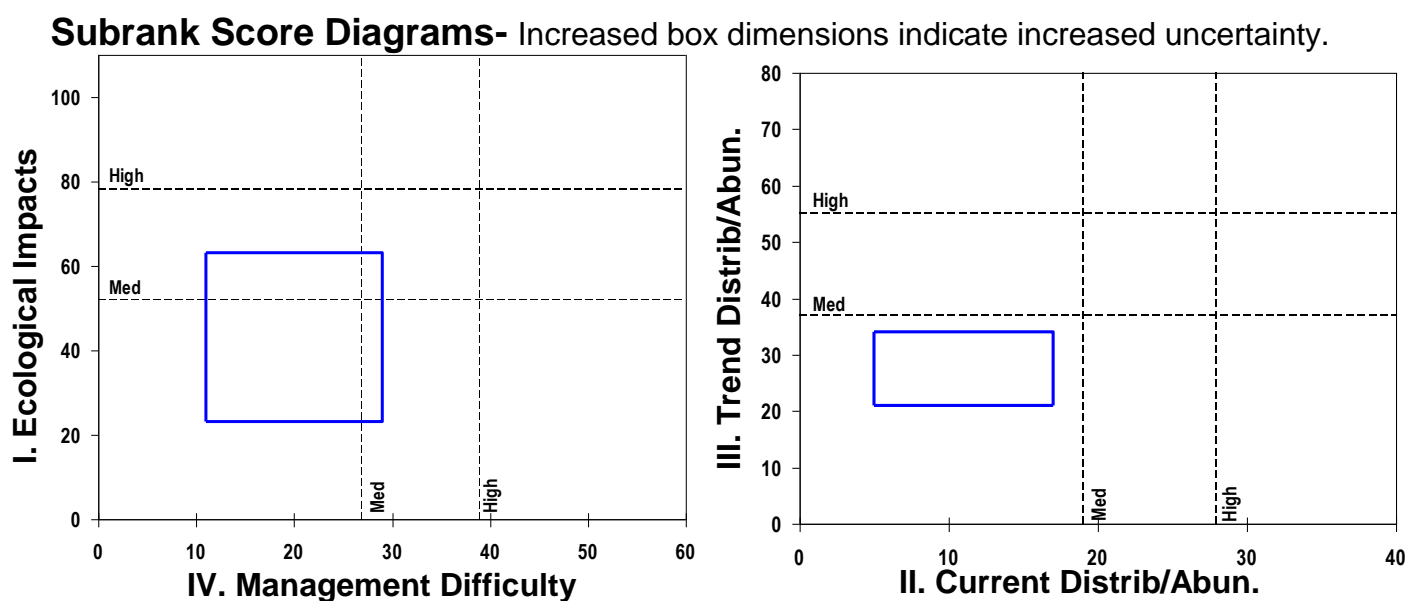
Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

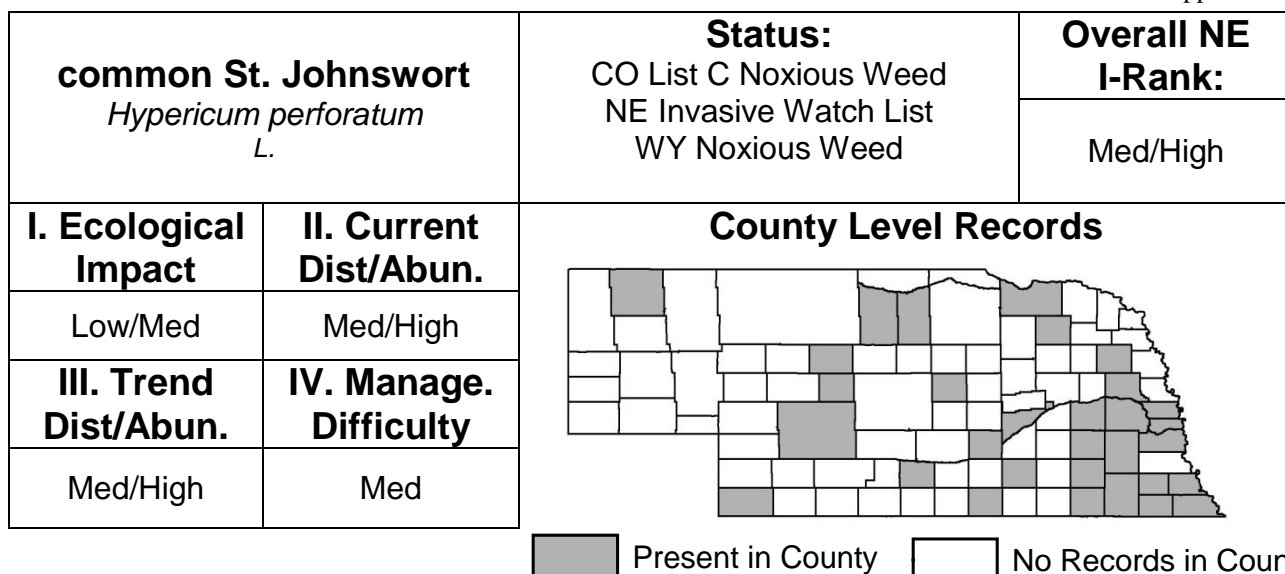




Comments:

In Nebraska it occurs mostly in dry waste places, corrals, and overgrazed bottomlands in the Panhandle (Kaul et al. 2006). Notable Survey Comments: Only problematic at one site I know of and not showing any increase beyond; potentially increasing, but not yet. Too few records for a good assessment.

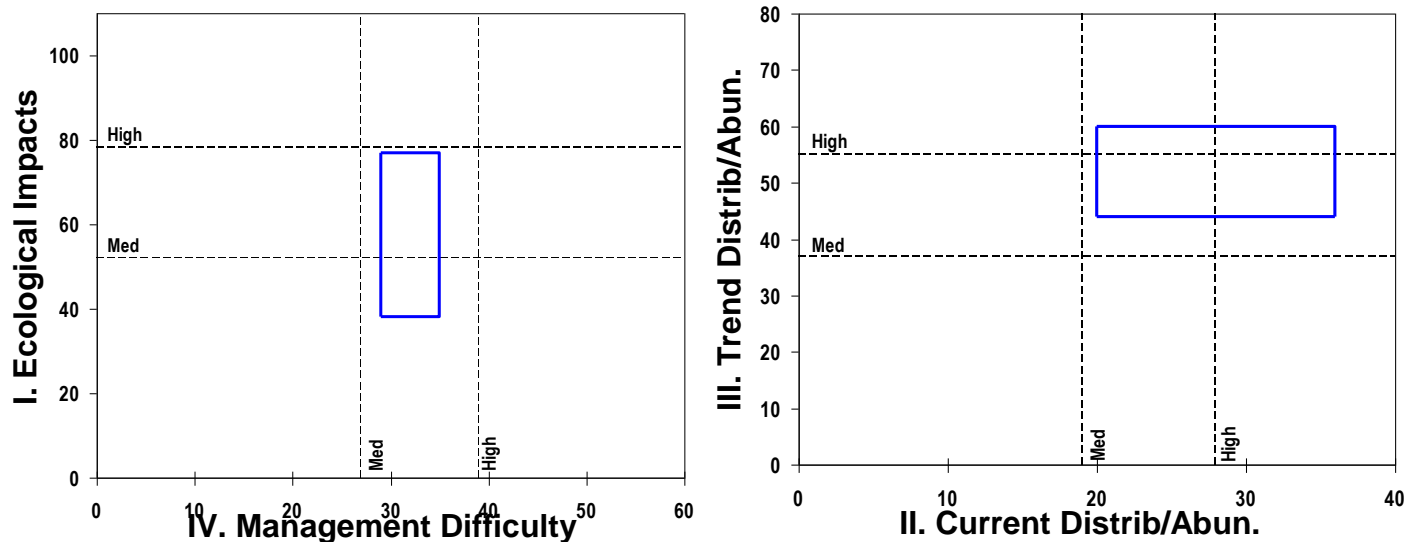


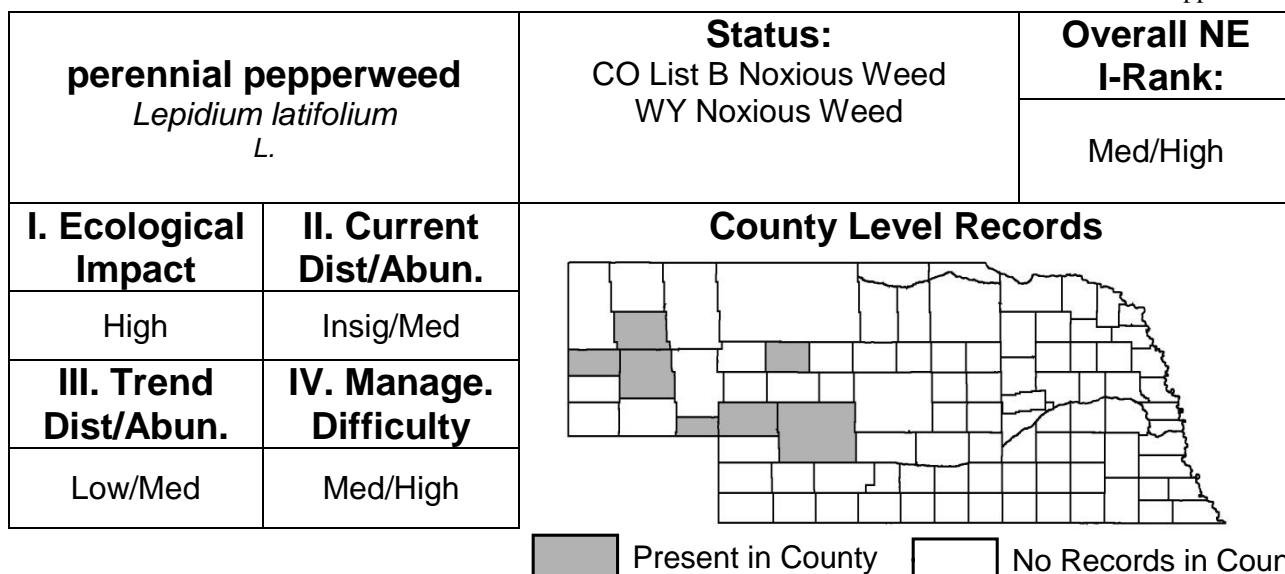


Comments:

This species is native throughout Europe, northern Africa, and much of Asia, and was documented outside cultivation in Nebraska by 1885 (Rolfmeier 2007). It occurs mostly in the central and eastern portions of the Great Plains (but also scattered westward) in prairies, pastures, and rangeland. Observations indicate that it is typically more abundant in sandy soil (Stubbendieck et al. 2003). Notable Survey Comments: spreading westward in North Nebraska. Recently becoming problematic in areas where previously established; has spread in the last 50 years and may have reached its maximum by now; relatively common in prairies in SE Neb. Appears to be expanding, appears to be increasing abundance; forms monoculture. Not spreading rapidly to new sites but infestations increase over time (PRIDE); Knox County promoted as alternative crop by extension specialist (Platte Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

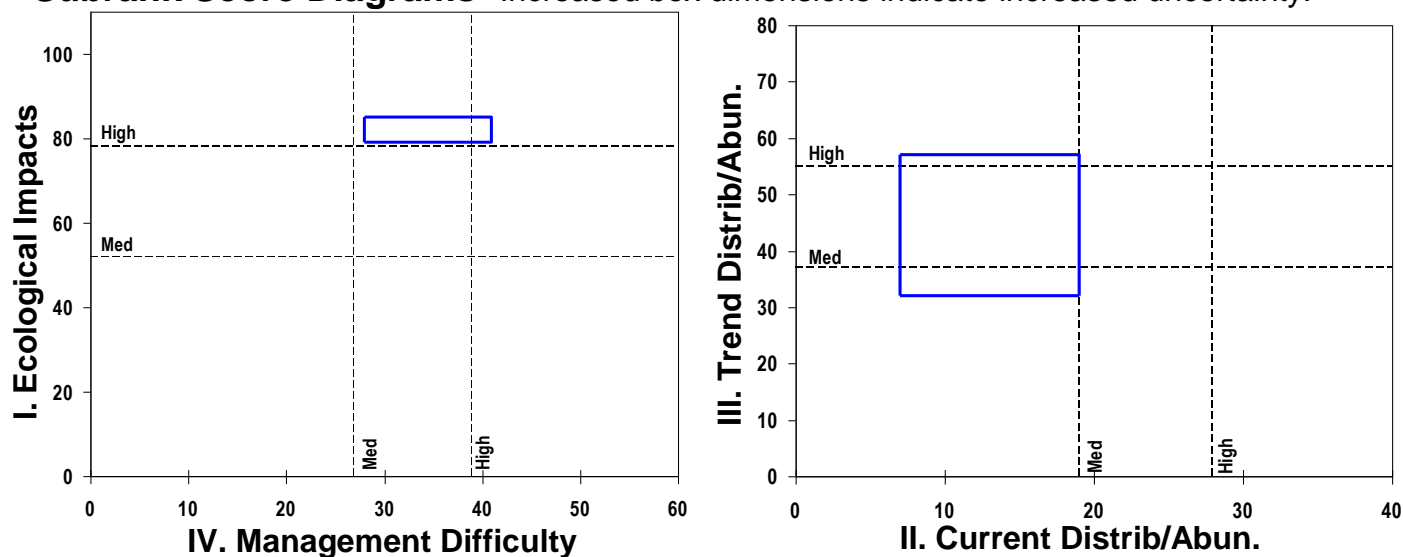


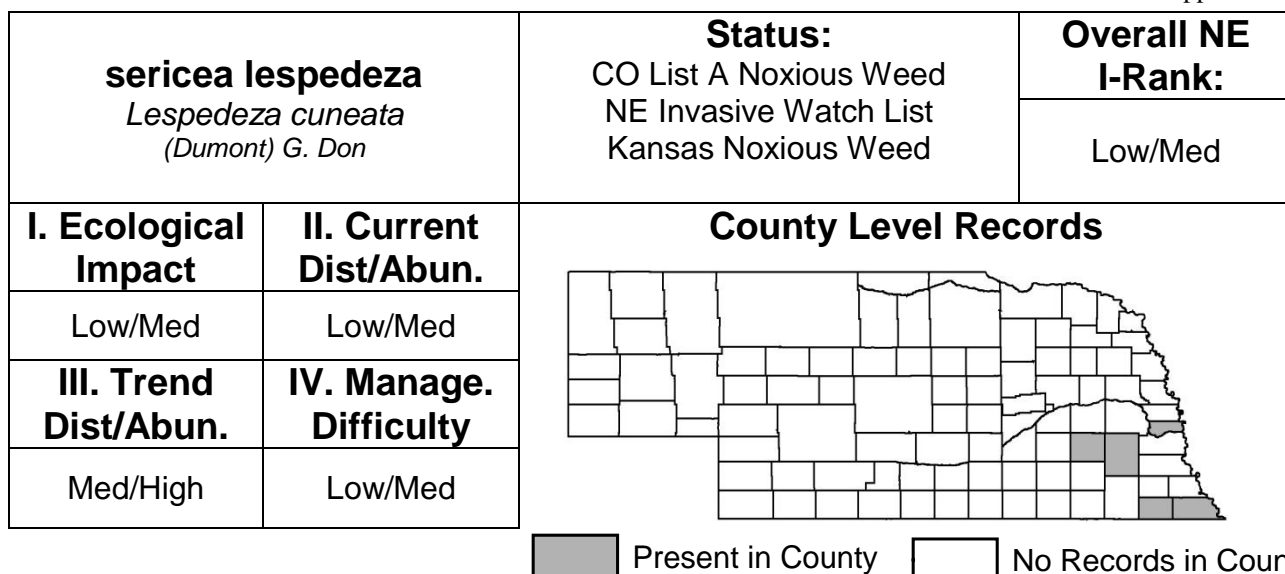


Comments:

Introduced from Europe, this species was first collected in Nebraska from Hooker County in 1961. It was observed to be abundant along the Platte River in the western part of the state since 1984, and can reproduce from rhizomes (Rolfmeier 2007). In Nebraska it occurs in fields and moist, sandy places, often becoming abundant in open disturbed ground along rivers in Western Nebraska and east to Lincoln County. Recently observations indicate it is increasingly common along the N. Platte and S. Platte Rivers, forming conspicuous colonies along floodplains. It appears to be spreading eastward and could become noxious (Kaul et al. 2006). Notable Survey Comments: mostly restricted to Platte River Valley; has increased in the Platte Valley in recent years.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

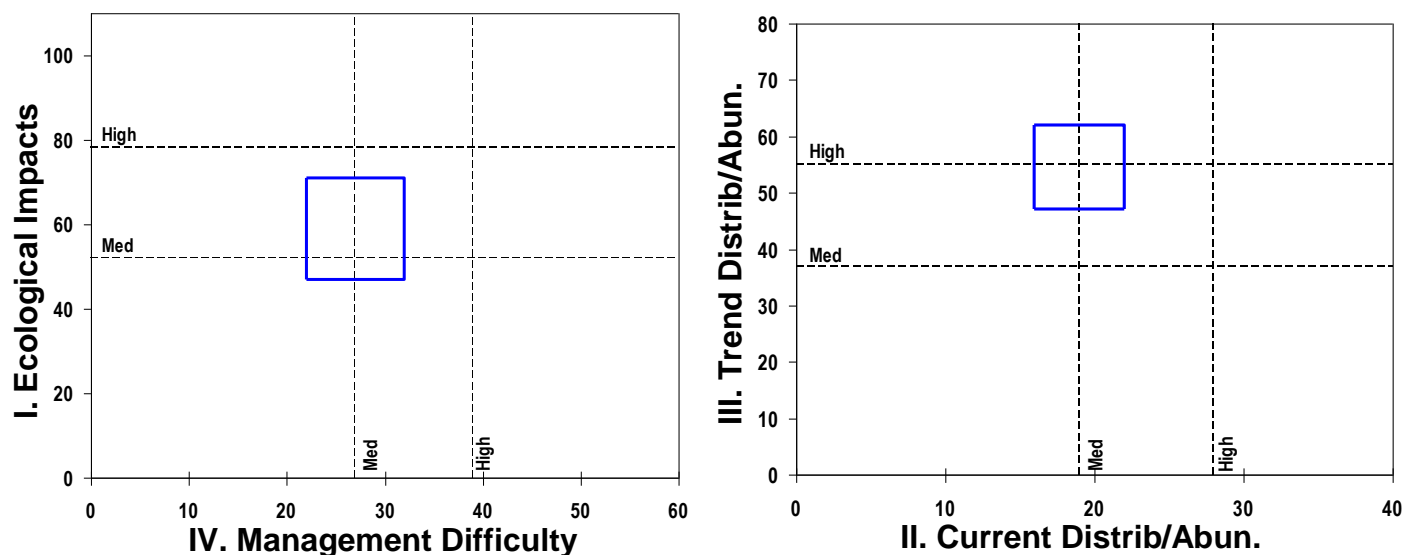


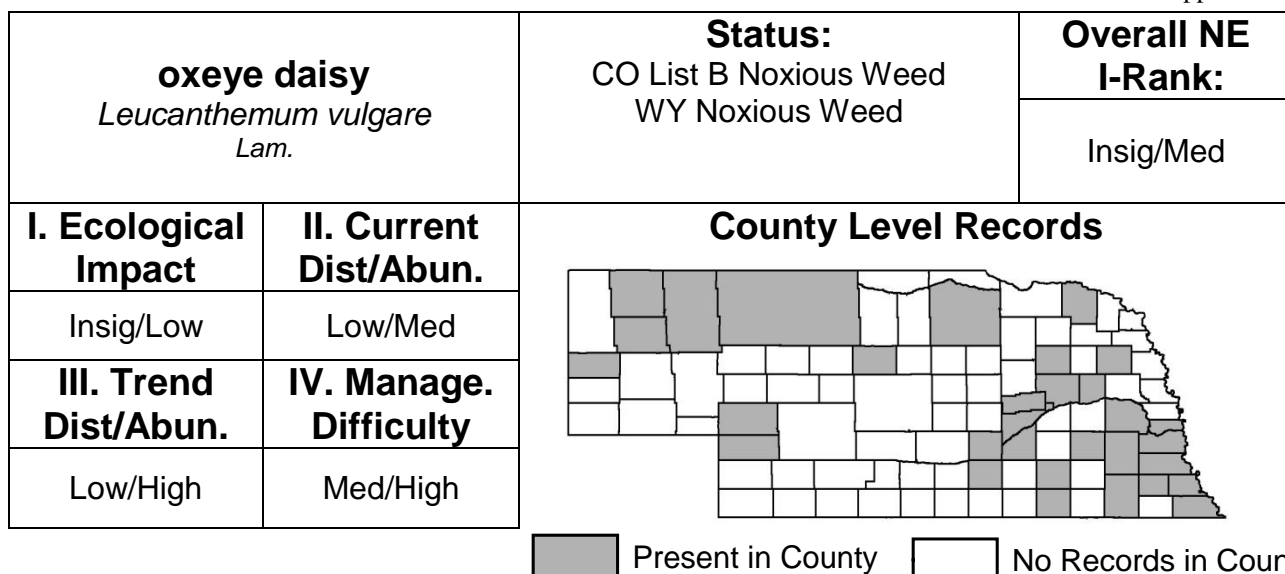


Comments:

This species is native to eastern Asia, and was first collected in Nebraska in 1974. Described as “Incredibly invasive”, it often out-competes native grasses in prairies (Rolfmeier 2007). Occurs mostly in the southeastern Great Plains in grasslands, abandoned fields, roadsides, stream valleys, open woods, thickets, and waste places, being most common in well-drained soils (Stubbendieck et al. 2003). In Nebraska it is becoming more extensive in SE Nebraska (Kaul et al. 2006). Notable Survey Comments: Has severe impacts on prairie and woodland communities in Eastern Neb.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

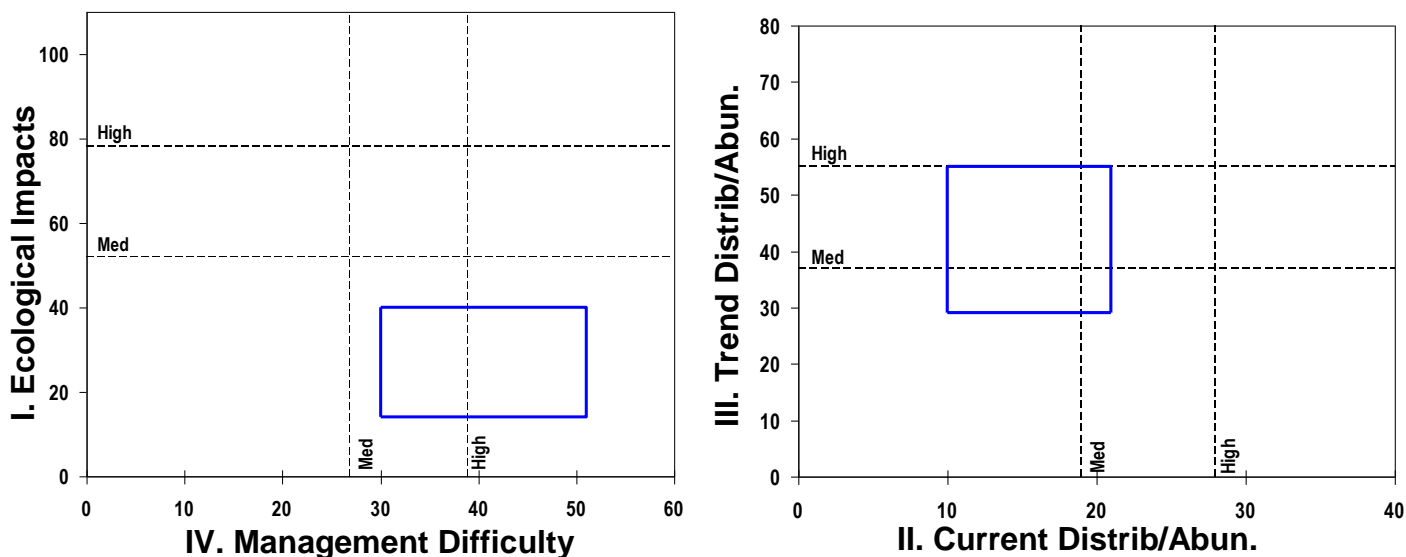


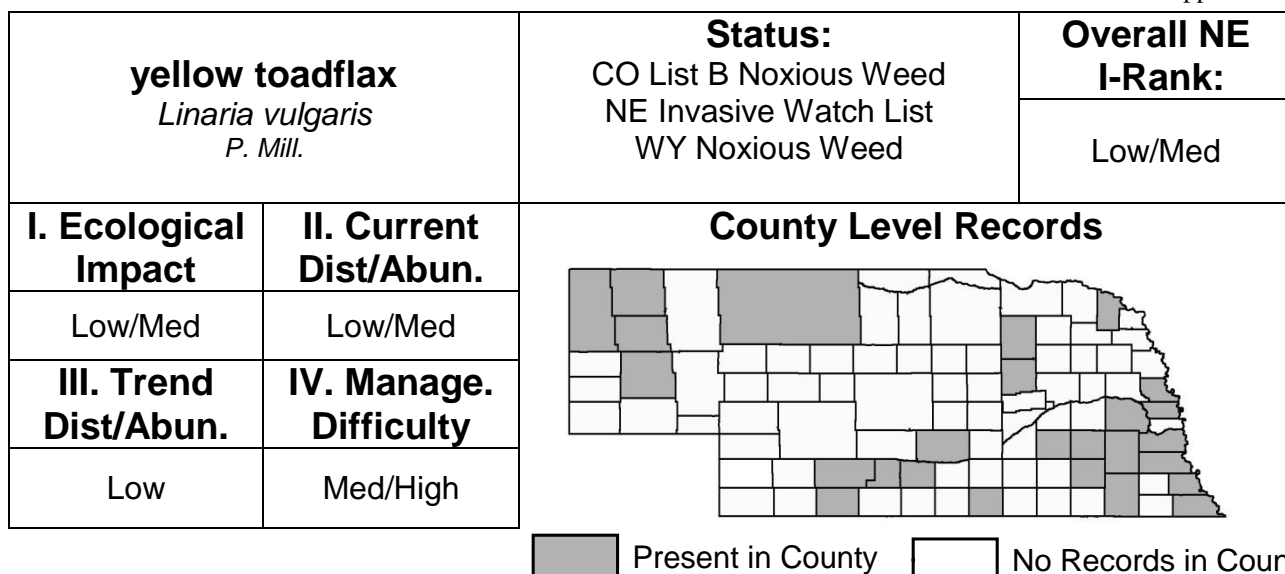


Comments:

This species is introduced from Europe and was widely planted in Nebraska along roadsides until recently. Ecological impacts are poorly known, though it produces abundant seeds with fairly long viability (Rolfmeier 2007). In Nebraska it occurs almost statewide, except the southwest and Sandhills, mostly along Roadsides, meadows, gardens, waste places (Kaul et al. 2006). Notable Survey Comments: Much of its range expansion due to highway seeding, which has been discontinued. Its persistence and invasiveness needs further study; seems to be spreading slowly, not likely to become a serious weed as in N, E, and W States; have noted populations in hay meadows and pastures in SE Neb. (Pawnee, Johnson, Gage Co.) and at Valentine Natl. Wildlife Refuge. Does not appear to be particularly aggressive; Dept. of Roads wildflower planting during 80s & 90s (Platte Valley); most populations along state roads because it was part of their seed mix (Twin Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

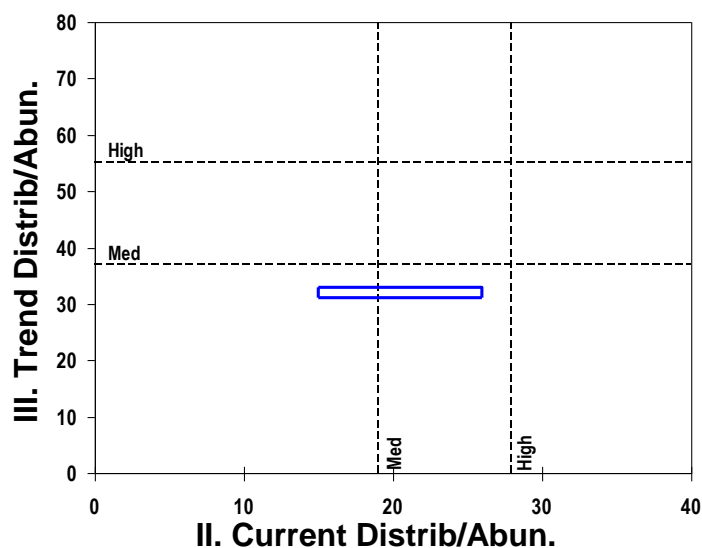
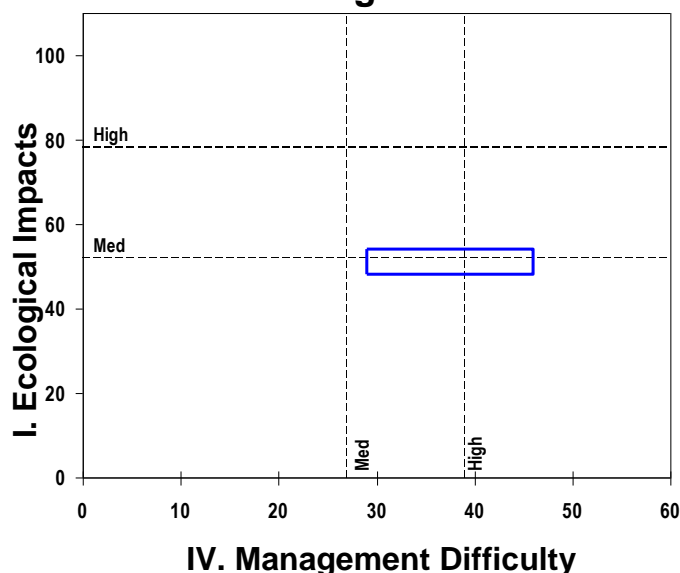


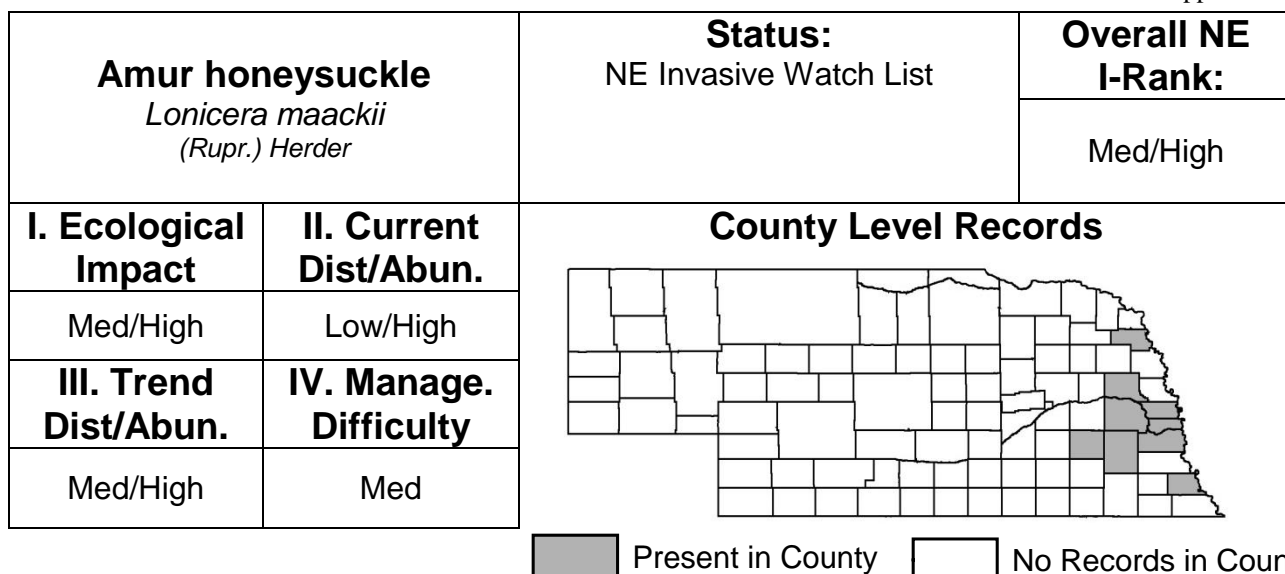


Comments:

This species is native to Europe, and was first collected in Nebraska in Nemaha County in 1883 (Rolfmeier 2007). It often occurs in disturbed open areas throughout much of Nebraska, but is absent in the Sandhills (Kaul et al. 2006). Notable Survey Comments: I doubt its ever naturalized in much of the state; My experience is that this is most often a roadside weed and is not common in native habitats; does not appear invasive in my experience; stable does not expand or spread, landowners are preventing spread by controlling it (PRIDE).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

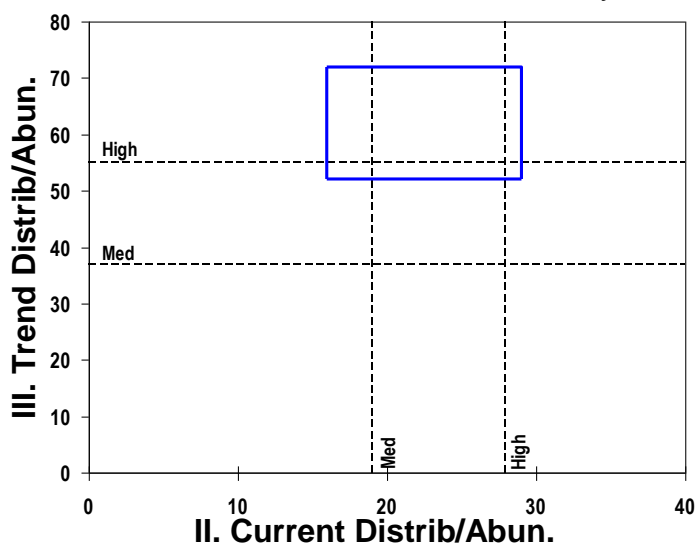
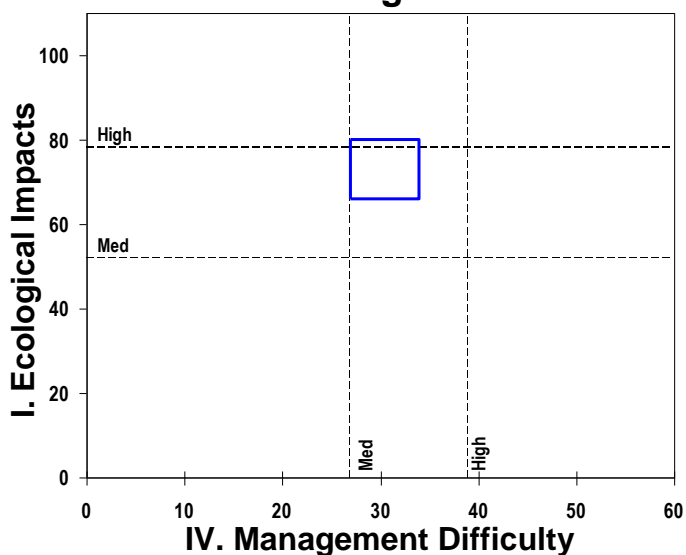


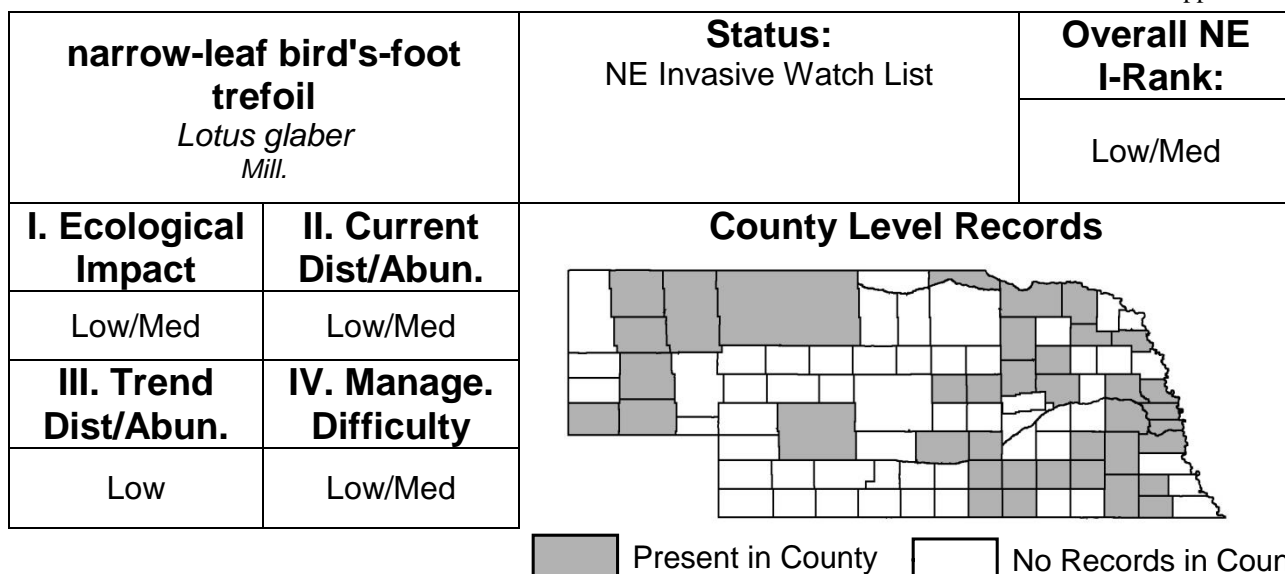


Comments:

This species, native of northeastern Asia, was first collected outside of cultivation in Nebraska in the 1990s, and it is rapidly becoming abundant in urban woodlands in Omaha (Roflsmeier 2007). It usually occurs in forest edges, and roadsides in eastern counties in Nebraska, but is not common (Kaul et al. 2006). Notable Survey Comments: Is starting to explode in areas where it has become established; already a locally serious problem and likely to become so elsewhere.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

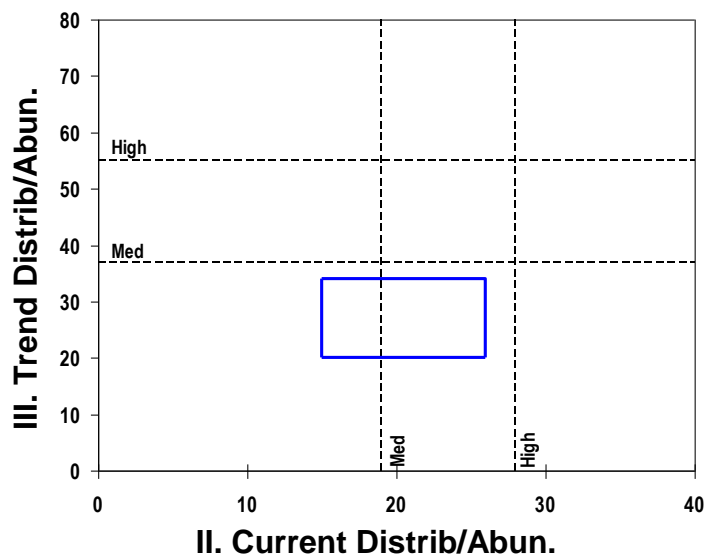
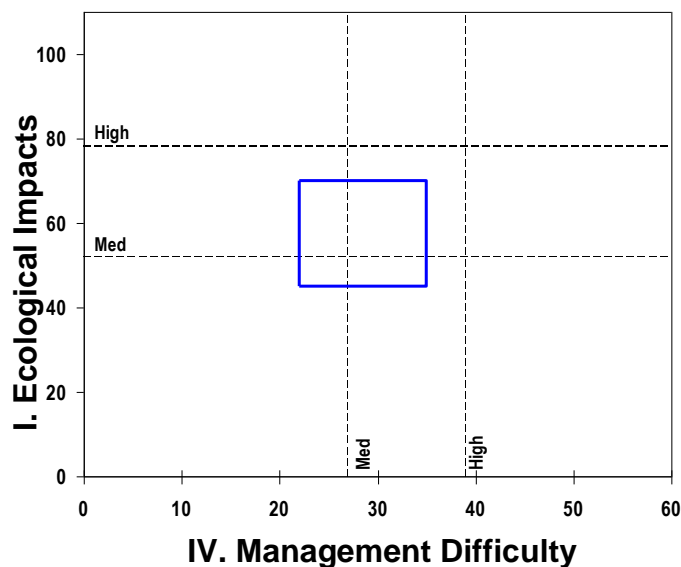


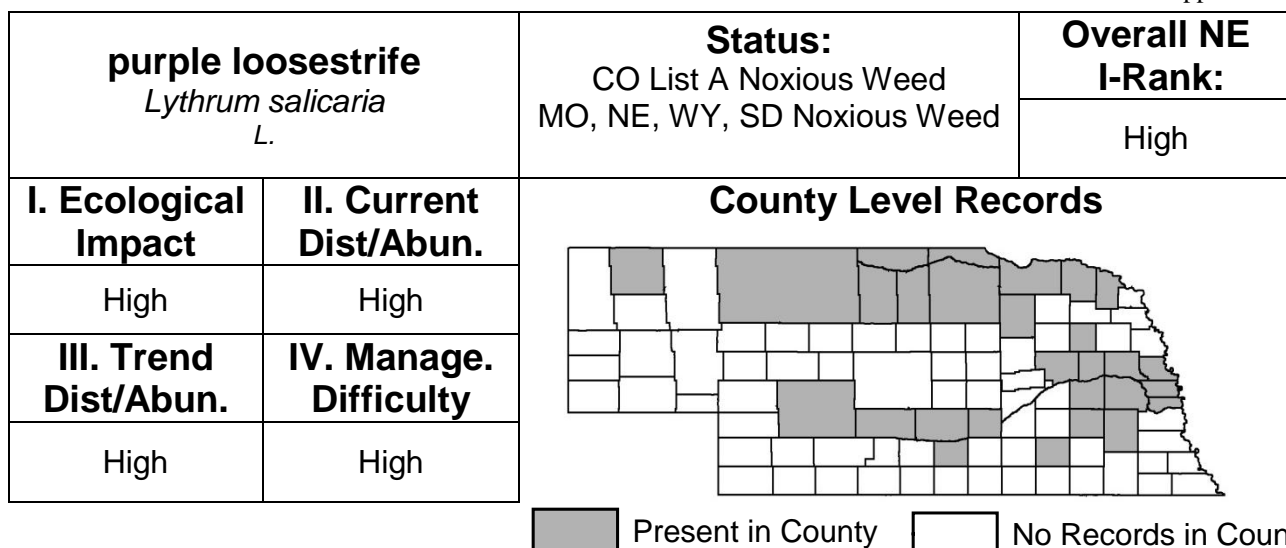


Comments:

This species is native to Eurasia was first collected in Nebraska in 1971. Ecological impacts are unknown (Rolfmeier 2007). Naturalized in some central and north-central Nebraska, being completely established in some mesic meadows (Kaul et al. 2006). Notable Survey Comments: Clay County has trefoil but no expansion has taken place (Twin Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

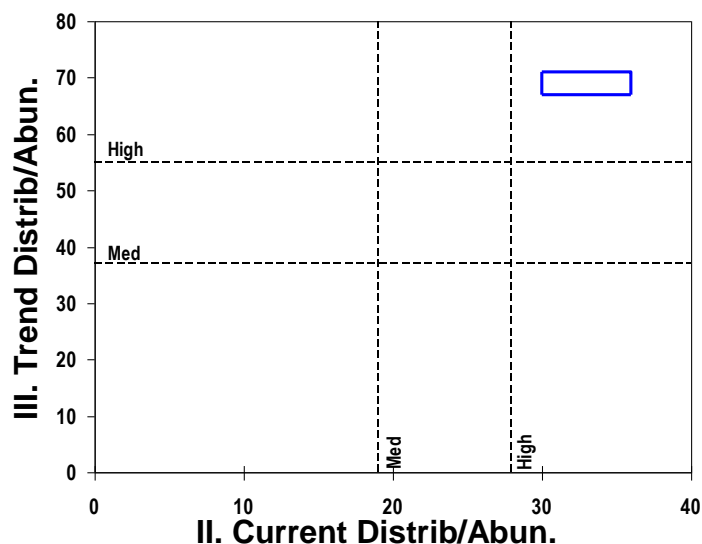
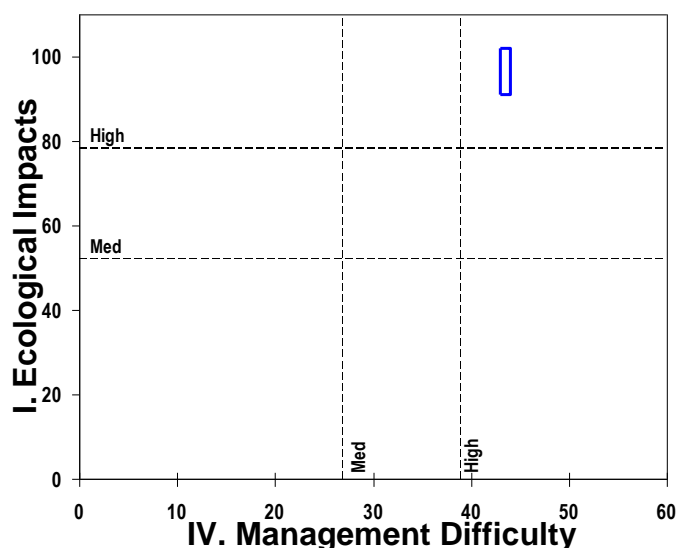


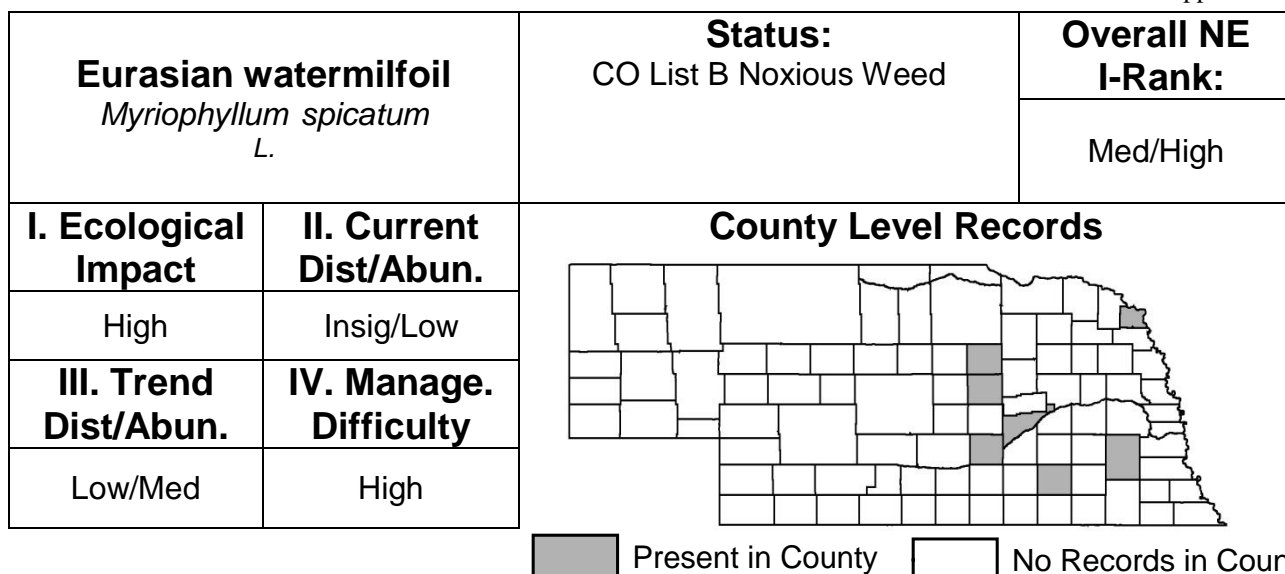


Comments:

This species is native throughout much of Eurasia, and the first Nebraska collection was made along the Niobrara River in 1972. It has spread along major rivers north of the Platte, and is a serious weed of wetlands (Rolfsmeier 2007). It is scattered across the Great Plains, but appreciably less common in the southwest portions. It usually occurs in marshes, along rivers, ditches, and wet meadows. It is perceived as rapidly and aggressively spreading and difficult to control (Stubbendieck et al. 2003). Notable Survey Comments: rapidly increasing in the Sandhills- and along the Elkhorn/Platte in eastern half Neb; Serious weed of wetlands, currently expanding into Sandhill wetlands; control efforts- chemical and bio- have insured that this plant will continue to be closely monitored (M. Niobrara); scattered infestations from Hershey to Brady in the Platte River Valley Area. Near Brady is pretty persistent (West Central); competition from *Phragmites* crowding. Purple loosestrife pulls out on shared locations (Platte Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

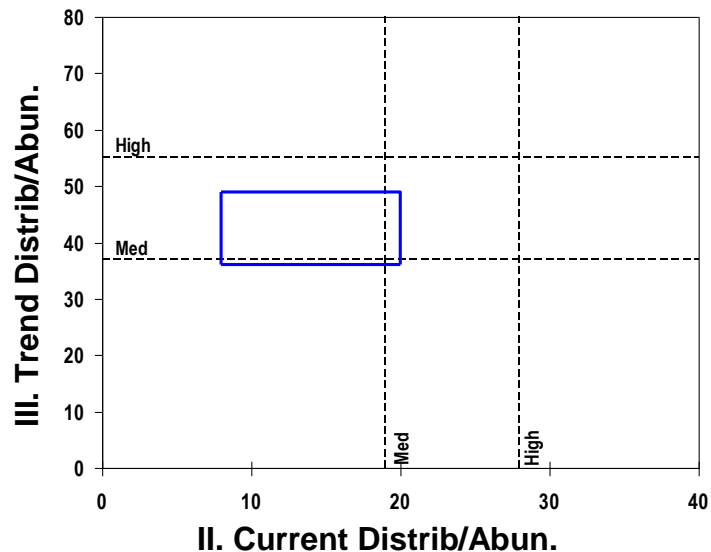
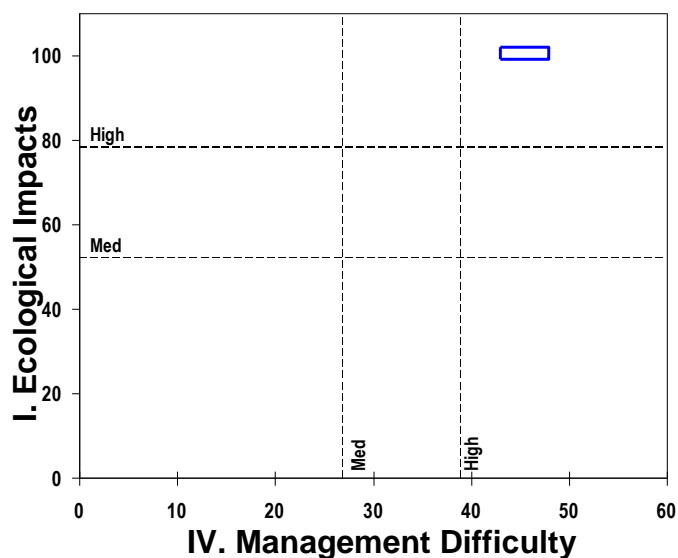


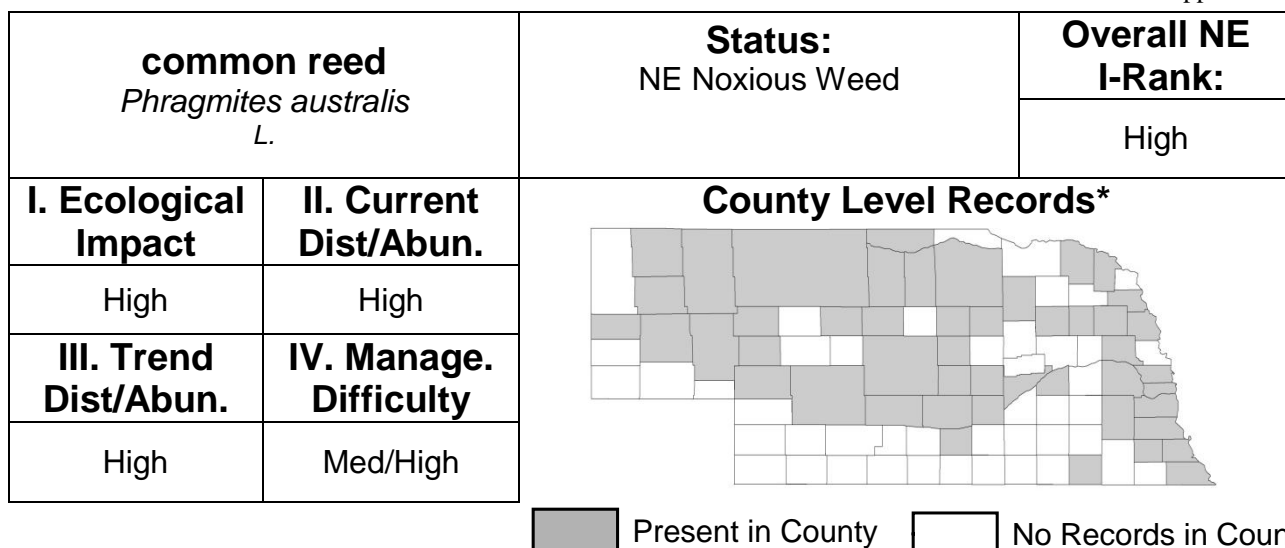


Comments:

This aquatic species was introduced into North America from Eurasia in the 1940s, and was collected in Nebraska by 1980 (Rolfmeier 2007). It has been observed in abundance in a few clear lakes and streams on sandy mud. It is perceived as “potentially invasive” (Kaul et al. 2006). Notable Survey Comments: rarely reproduces here, most of spread was probably due to introductions in fisheries; seems to be declining after initial population increase.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.



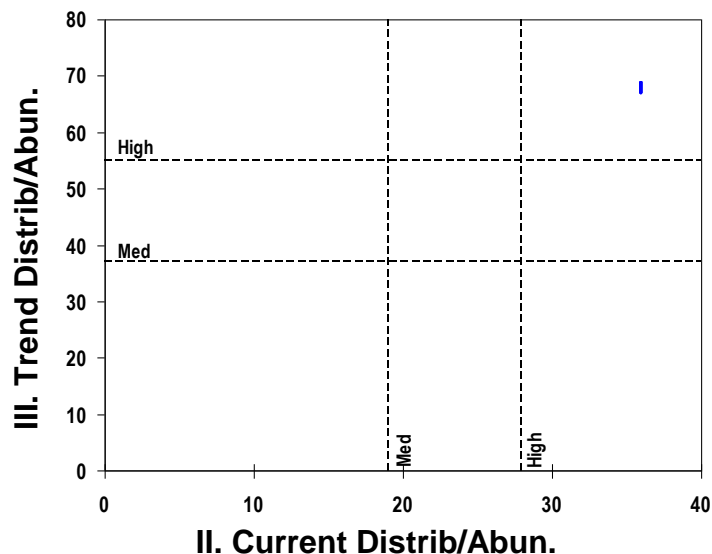
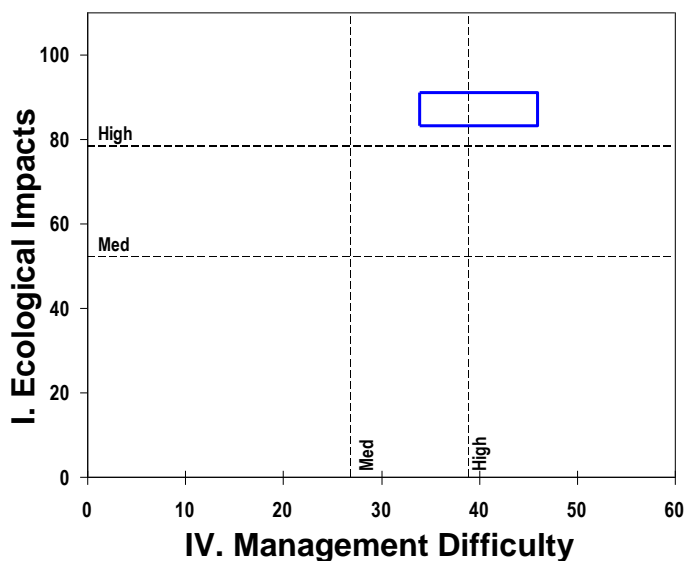


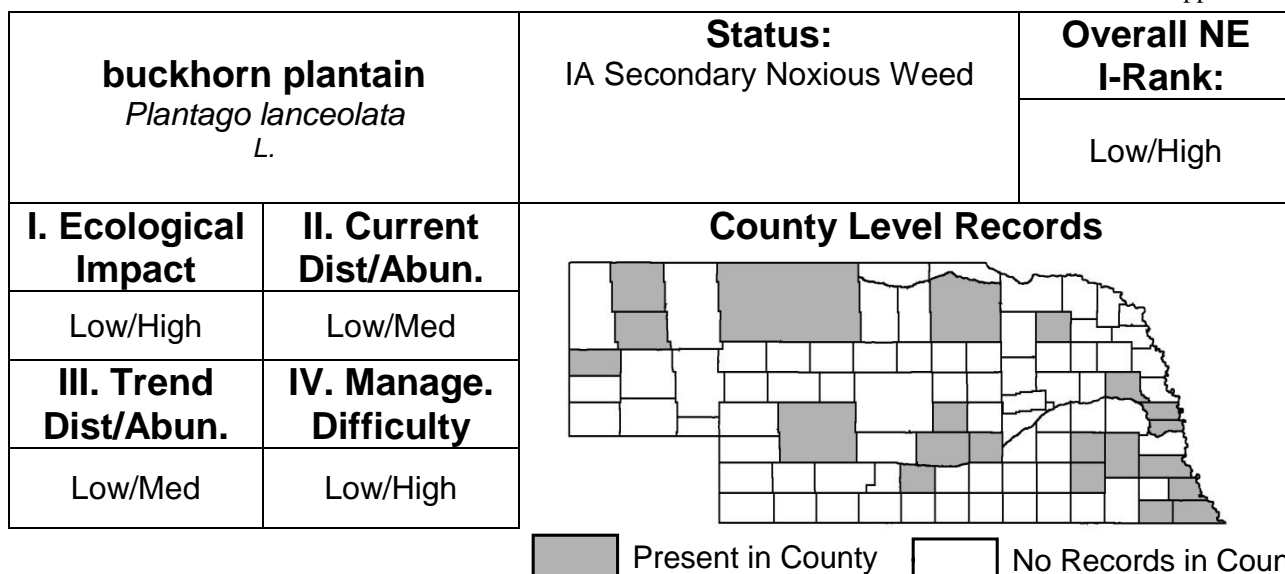
*Map does not distinguish between native and non-native types

Comments:

Rolfsmeier (2007) uses the *ssp. australis* designation to distinguish Eurasian plants from the native (*ssp. americanus*). Kaul et al. (2006) combines into a single taxonomic unit, but noting that some of the *Phragmites australis* present in Nebraska “no doubt represent introductions” (Kaul et al. 2006). In Nebraska it can form monocultural stands in marshes very quickly (Rolfsmeier 2007). It occurs throughout the Great Plains, forming dense patches in wet soils (Stubbendieck et al. 2003). Notable Survey Comments: the non-native phenotype does not seem to have spread north of the Platte, though it could become problematic when it does; European genotype expanding. Native genotype stable; could see expansion into Sandhills wetlands; Very serious problem on Platte River. Seems to be spreading rapidly; most infestation in our 4 county area are native (PRIDE); only native *Phragmites* has been noted (M. Niobrara); Hershey on east is the worst (West Central); Riparian areas on Platte, increasing >10%/year, riparian zones (Platte Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

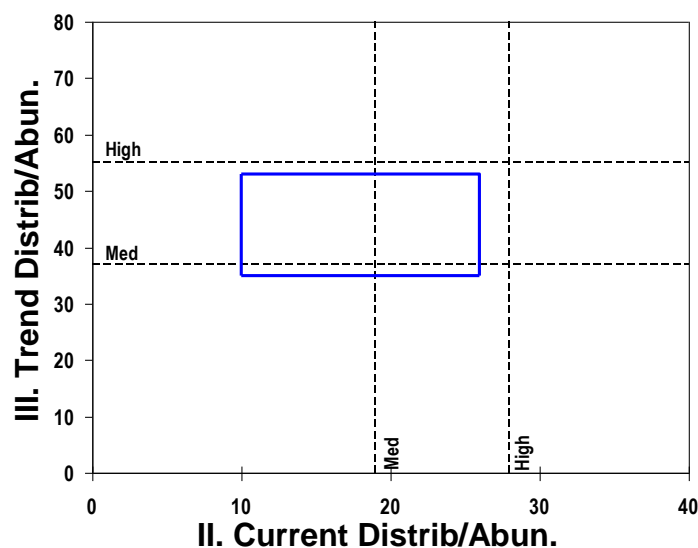
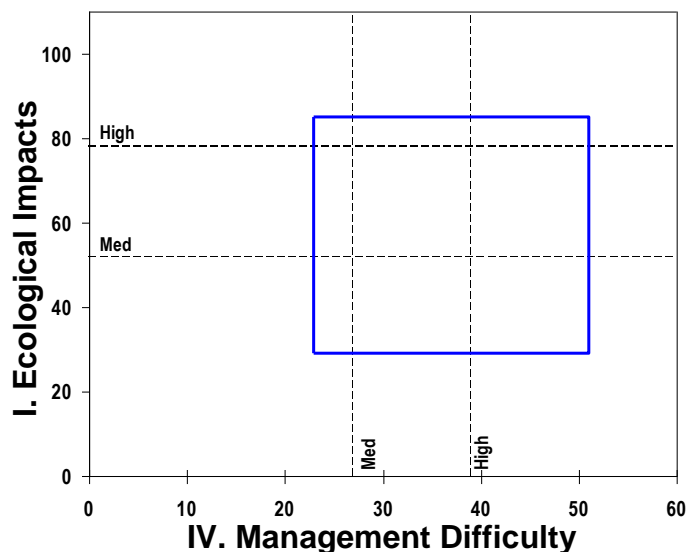


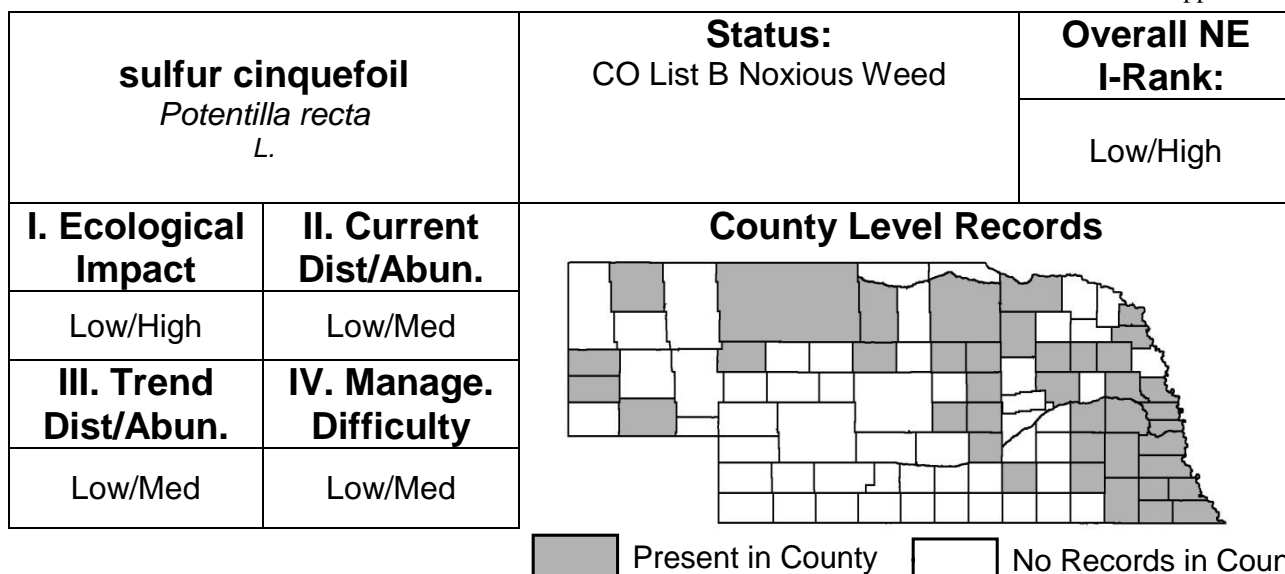


Comments:

This plant native to Eurasia, and occurs mostly in the central and southern portions of the Great Plains. Found most often in, lawns, golf courses, sod farms, meadows, waste places, pastures, and roadsides (Stubbendieck et al. 2003). It is known to be common in eastern Nebraska counties since the 1880's, but it is also scattered westward, though not in Sandhills (Kaul et al. 2006). Notable Survey Comments: has been spreading onto native hay meadows in the eastern Sandhills though its current impact is hard to judge; I have never seen this in a native plant community. My experience is that it is a lawn weed (at least in my yard where it is doing extraordinarily well).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

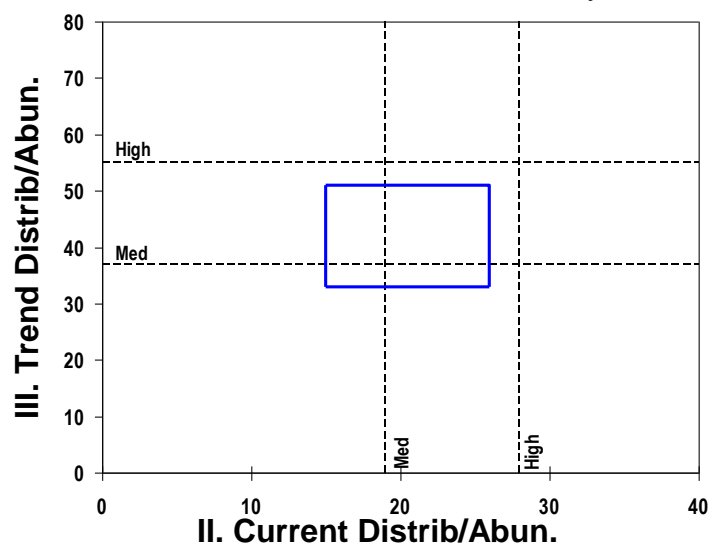
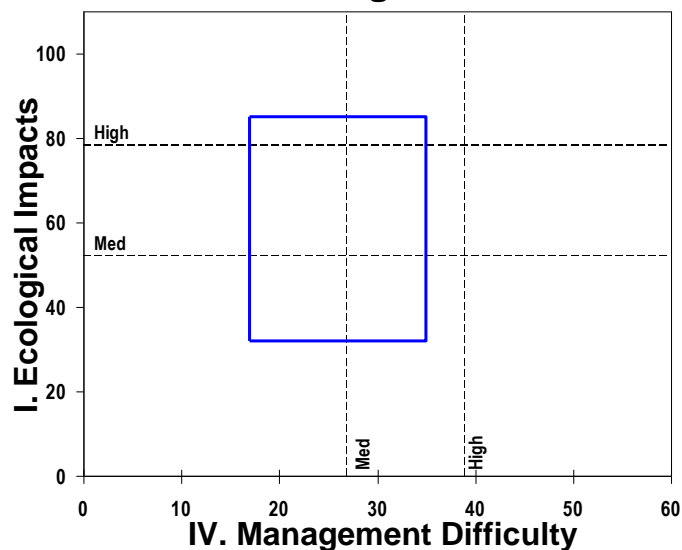


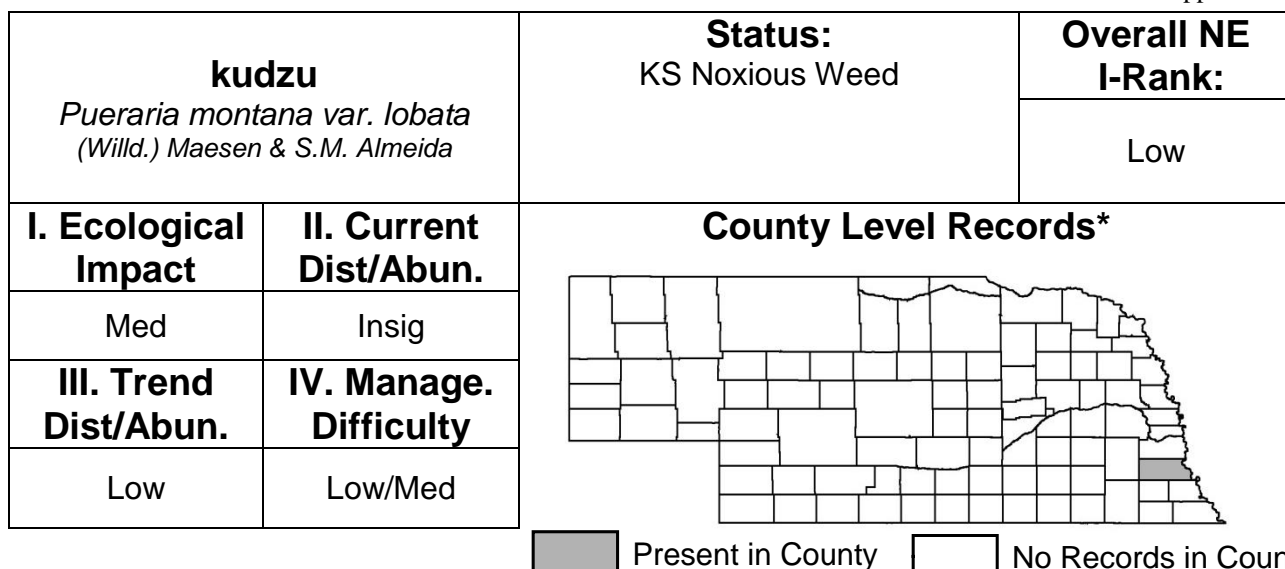


Comments:

This species is native to Eurasia, and was first collected in Nebraska by 1926. It can invade native grasslands and form monoculture stands in part of its range (Rolfmeier 2007). It occurs in disturbed places such as roadsides, gardens, and abandoned fields, occasionally in open woods and native prairies or in wet or sandy soil. It is most common in the eastern half of Nebraska (Kaul et al. 2006). Notable Survey Comments: seems to be exploding in weedy hay meadows of the eastern Sandhills and is rapidly expanding westward. Long established in the SE; Species is generally scattered in native prairie habitats of eastern. Neb. And does not appear to currently have major impacts on biodiversity. Needs to be monitored.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.



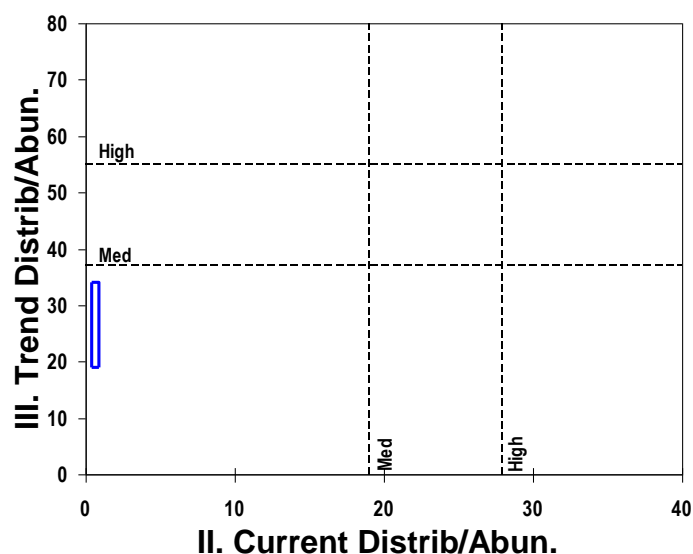
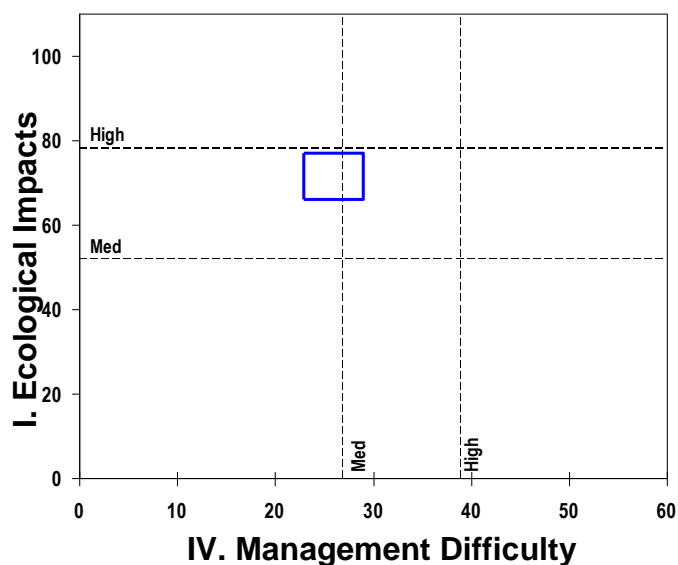


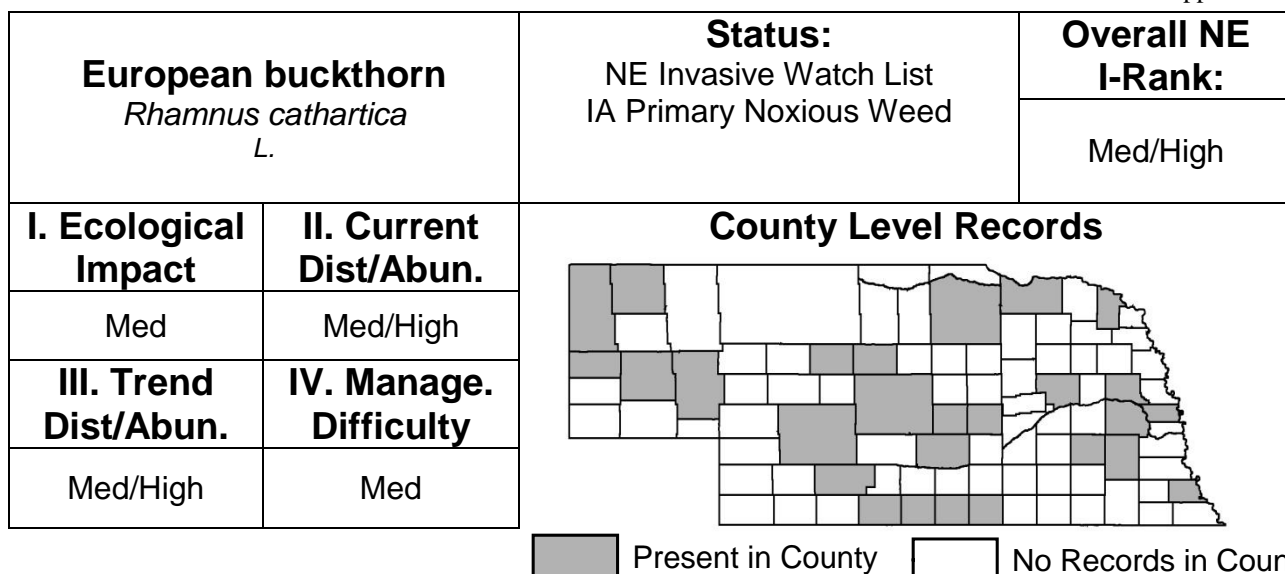
*known from a single location now extirpated

Comments:

This Asian species is mostly limited to the southern and southeastern portions of the Great Plains, occurring in well drained soils, in disturbed areas and forest edges (Stubbendieck et al. 2003). Although it requires relatively mild winters to survive, a single large colony in Otoe County, Nebraska was alleged by locals to have persisted more than 10 years before being eradicated by herbicide in 2003 (Kaul et al. 2006). Notable Survey Comments: not likely to reproduce here; extirpated; I think this has only been noted once in NEB in Otoe Co and has been eradicated.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

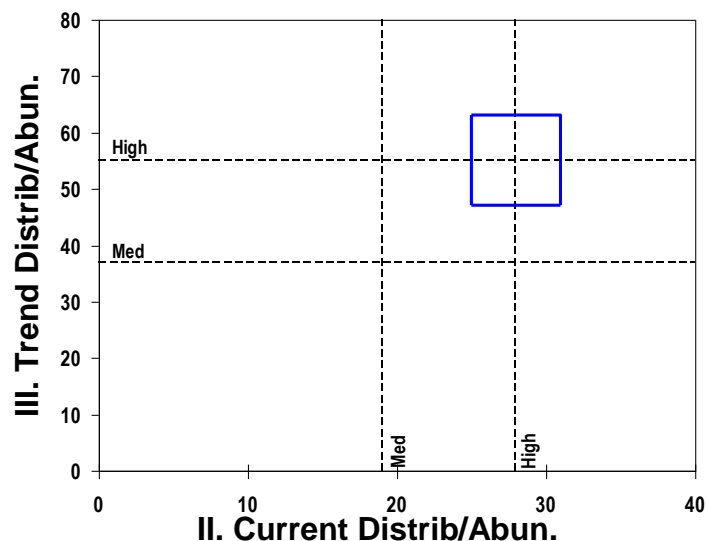
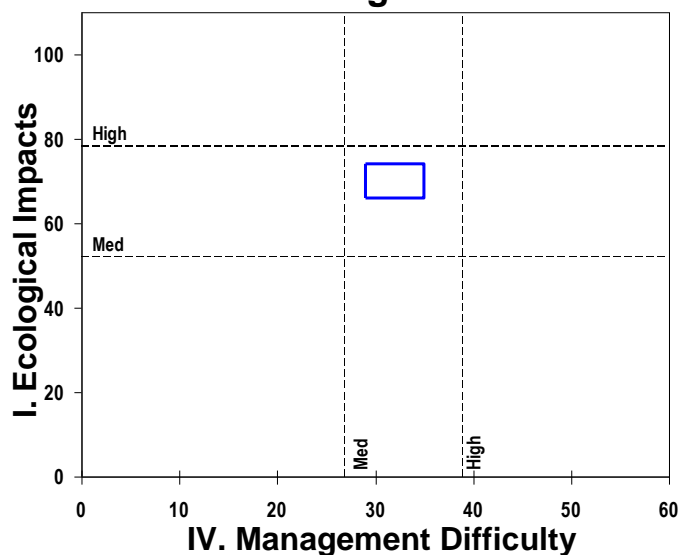


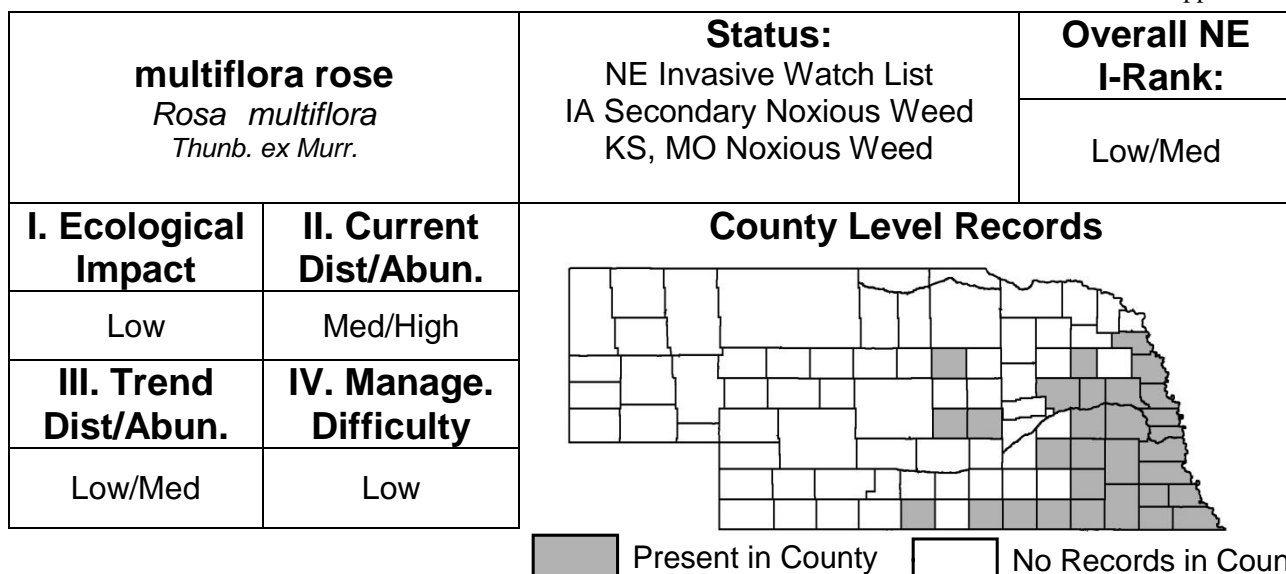


Comments:

This plant is native to Eurasia, and was collected in Nebraska outside of cultivation by 1987. It seems to spread in urban environments and threatens natural forests in eastern portions of Nebraska (Rolfmeier 2007). Within the Great Plains, it is most common in the central and northern portions (Stubbendieck et al. 2003). It is known to be an aggressive nuisance, often overtaking shrubs, hedges, and fence lines; the seeds are readily spread by birds (Kaul et al. 2006). Notable Survey Comments: Becoming problematic in parts of the east- and rapidly expanding in urban situations in the west- impacts in natural habitats is still limited in much of the state.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

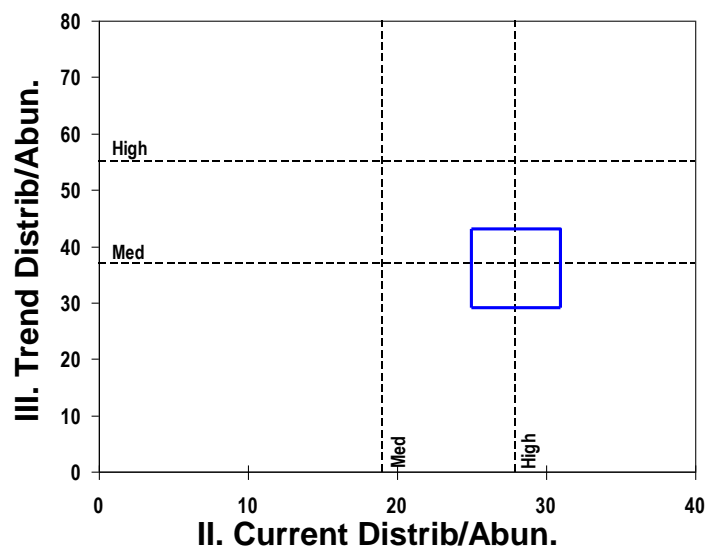
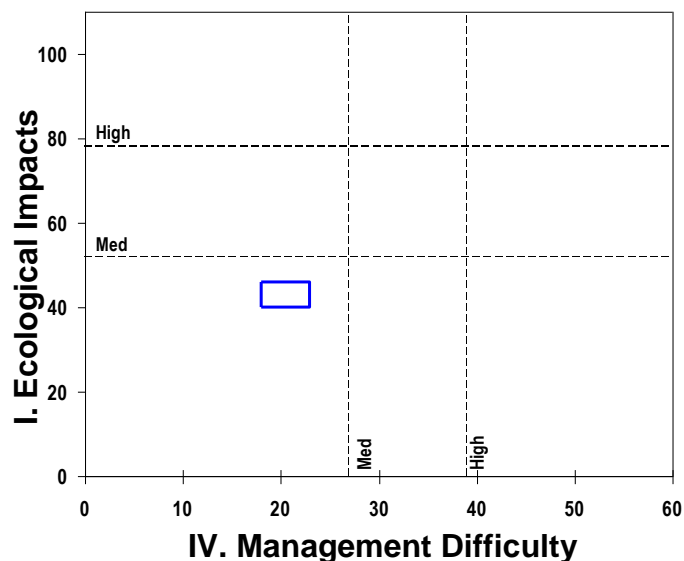


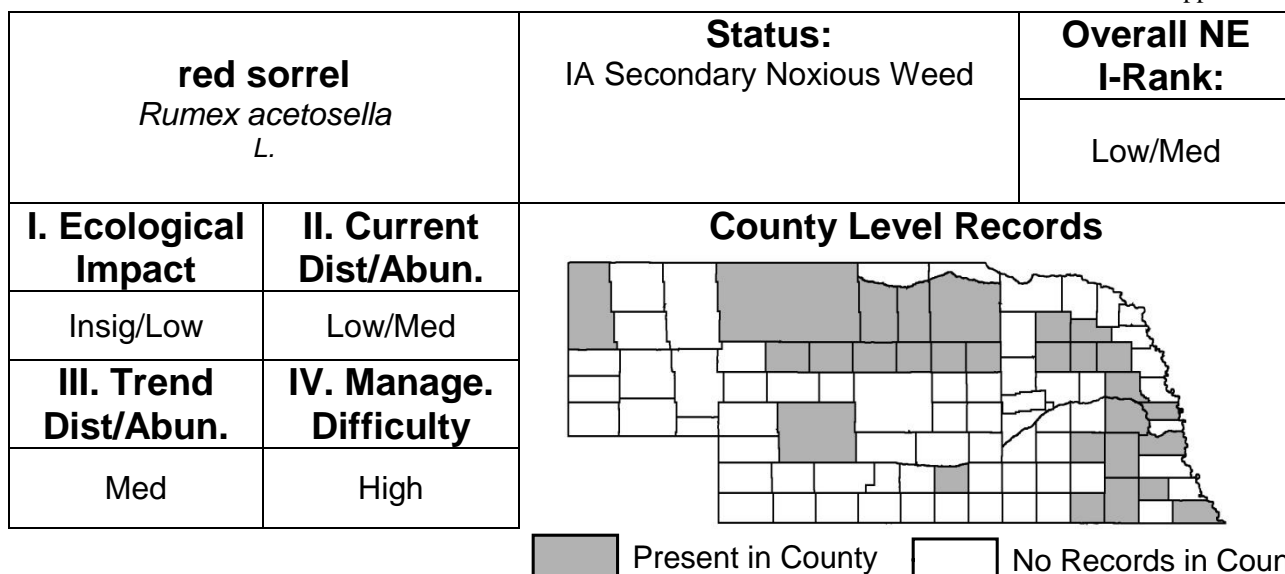


Comments:

This species is native to Japan, Korea, and eastern China, and was recorded in Nebraska by 1974 (Jefferson and Richardson Counties). It is common in the southeast quarter of Nebraska and is spreading north and west (Kaul et al. 2006). Notable Survey Comments: locally problematic-though it has been for some time; Widespread and fairly common throughout range.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

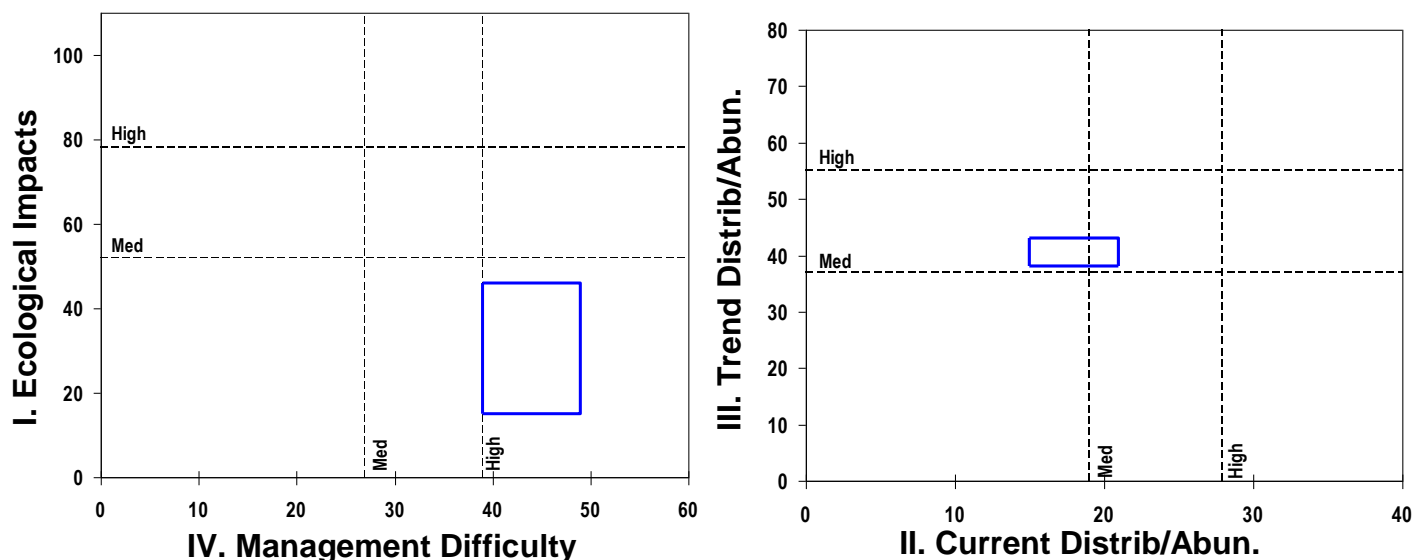


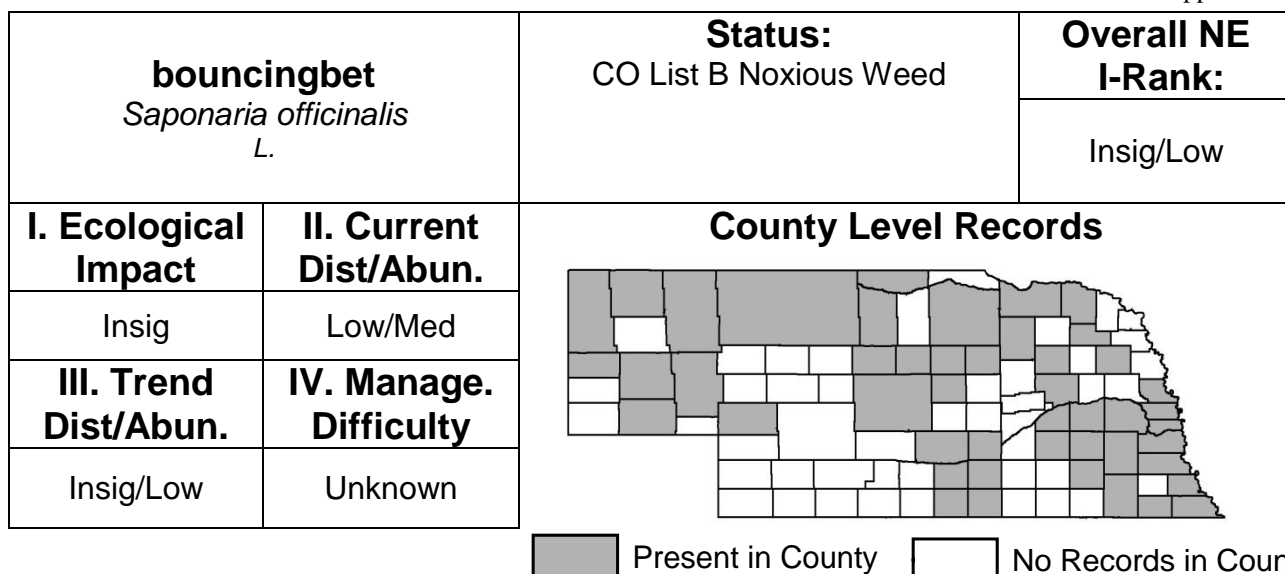


Comments:

In Nebraska, this Eurasian species is commonly observed in disturbed, sandy soils in prairies, roadsides, and waste ground. It occurs most frequently in the east and north central portions of Nebraska, including the eastern Sandhills (Kaul et al. 2006). It is also scattered throughout much of the Great Plains (Stubbendieck et al. 2003). Notable Survey Comments: widespread but mostly limited to highly disturbed habitat; generally in disturbed areas. Don't think this is a serious weed in Nebraska.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

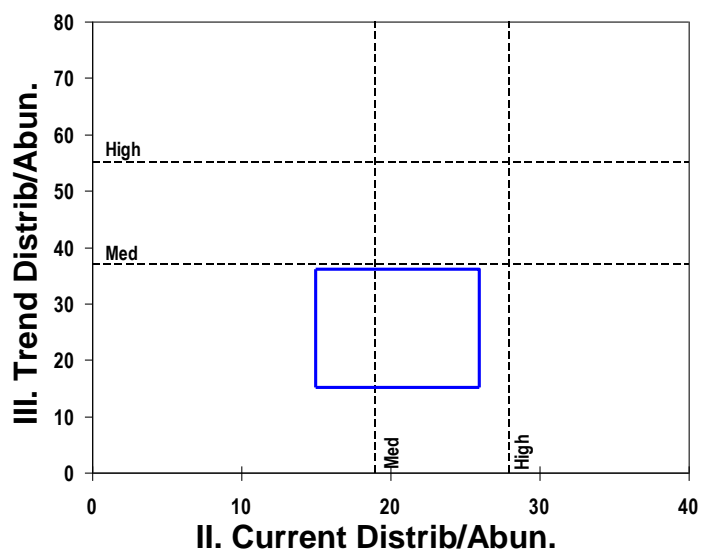
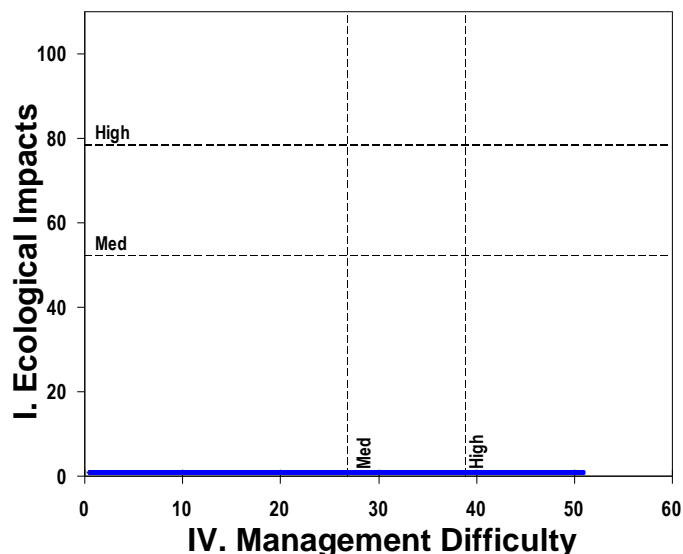


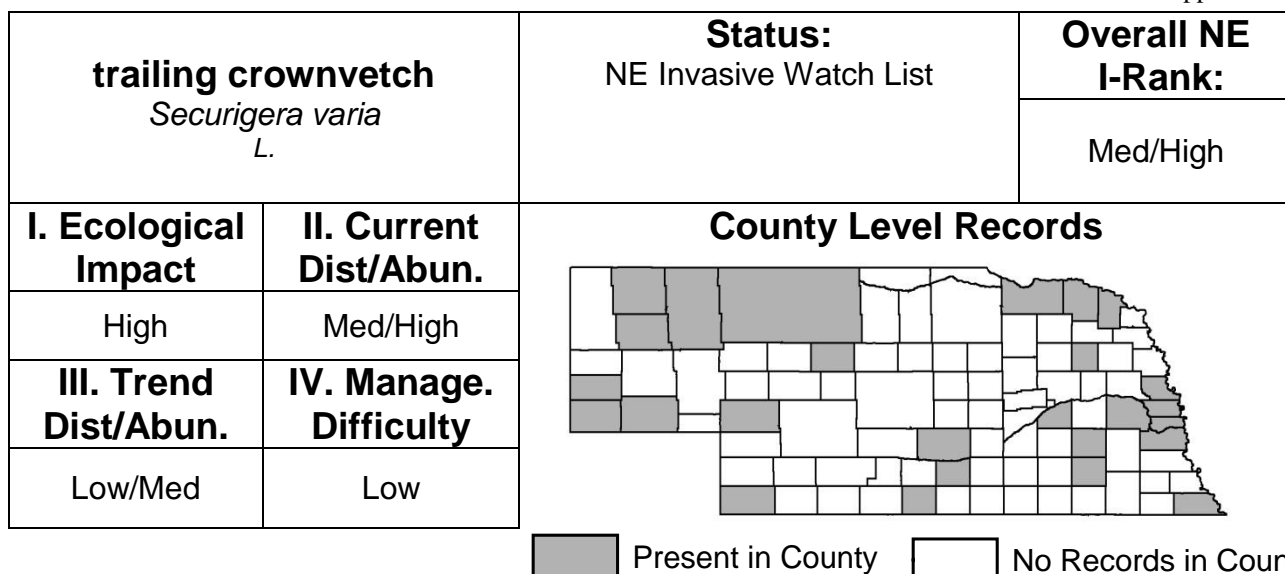


Comments:

This escaped ornamental from Eurasia is scattered throughout the Great Plains, mostly in waste places, roadsides, and fence rows (Stubbendieck et al. 2003). It was first collected in Nebraska in 1890, and is now naturalized nearly statewide (Kaul et al. 2006). Notable Survey Comments: mostly persistent along roadsides and decreasing in many places ; mostly a roadside plant, seldom in native ecosystems. Never common enough to be a problem; generally uncommon roadside weed or in heavily grazed pastures; seen around old farmsteads (PRIDE).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

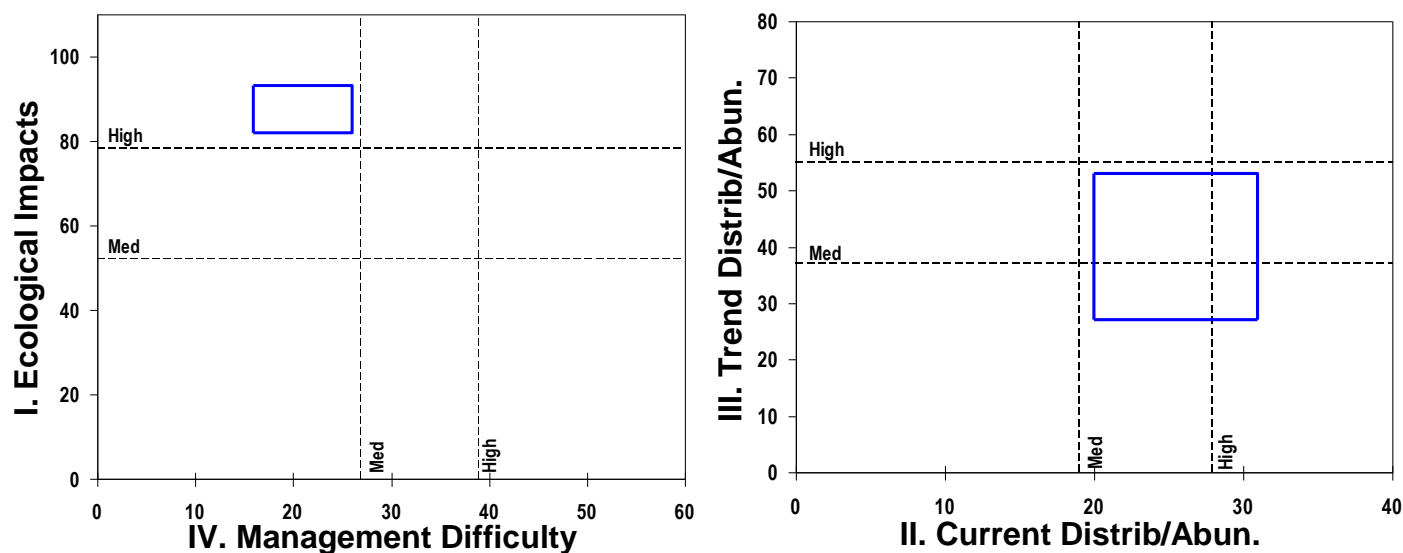


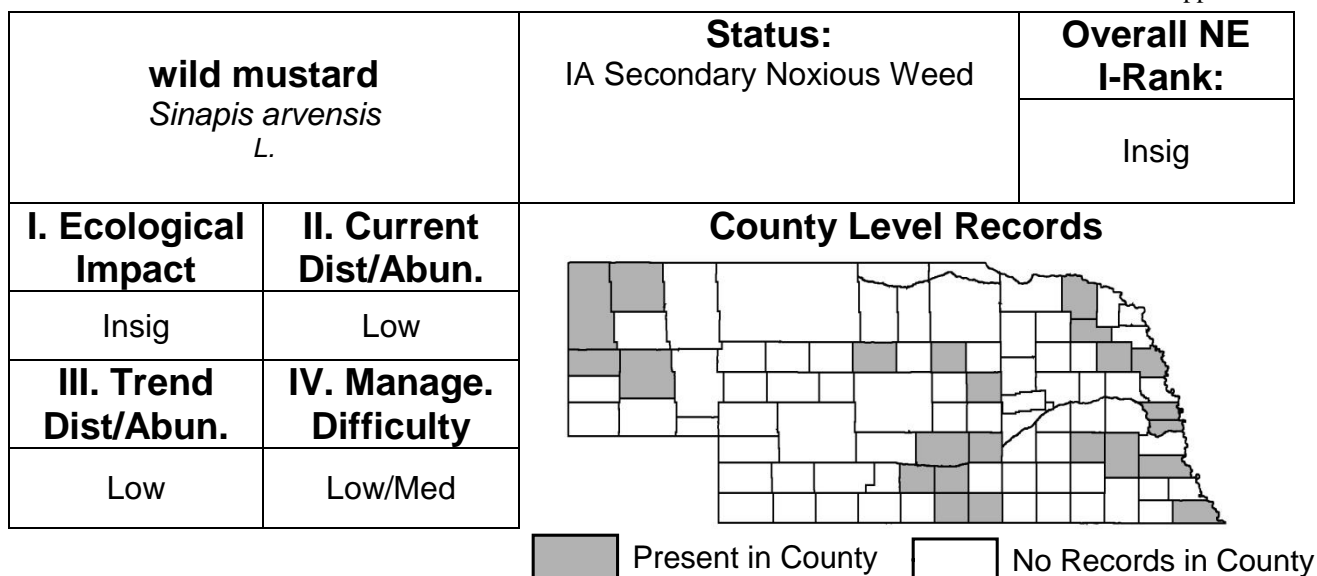


Comments:

This plant is native to the Mediterranean region, and was introduced for purposed of erosion control. It seems to have escaped into native habitats where it can smother most vegetation (Rolfsmeier 2007). It is resistant to herbicides and is difficult to control where it is not wanted (Kaul et al. 2006). Notable Survey Comments: shows potential to become problematic, present impacts are not very serious; serious invader of prairie communities in E. Neb where it has been planted by roads dept., particularly bad at Burchard Lake, Pawnee Co; small infestations, don't increase (PRIDE).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

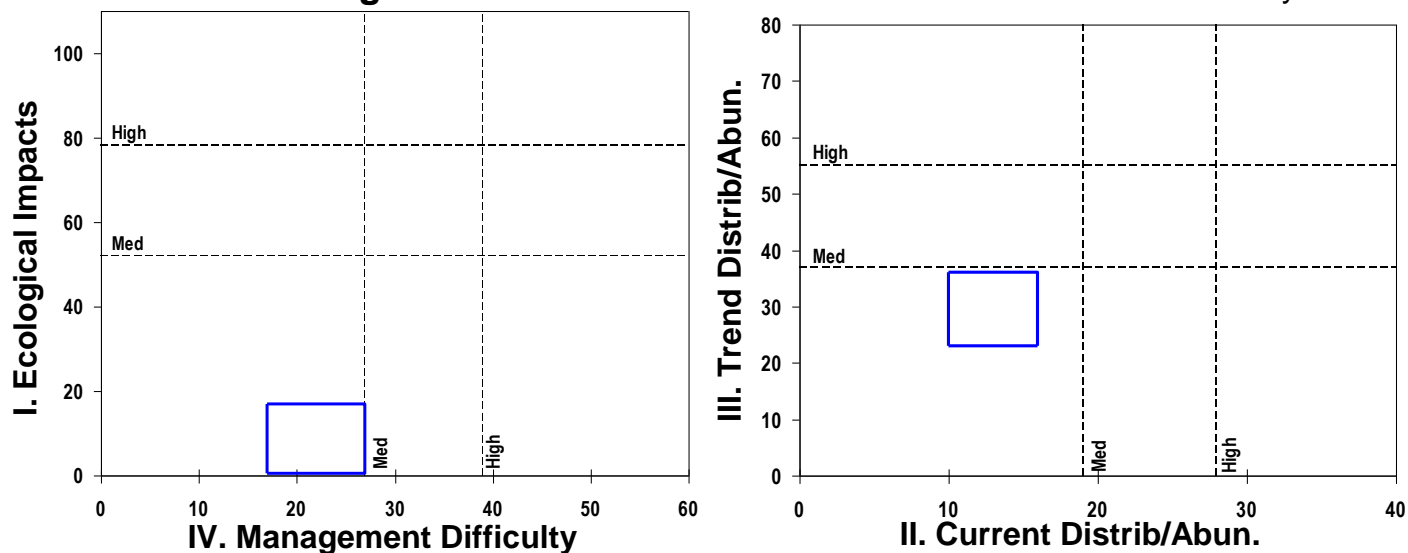


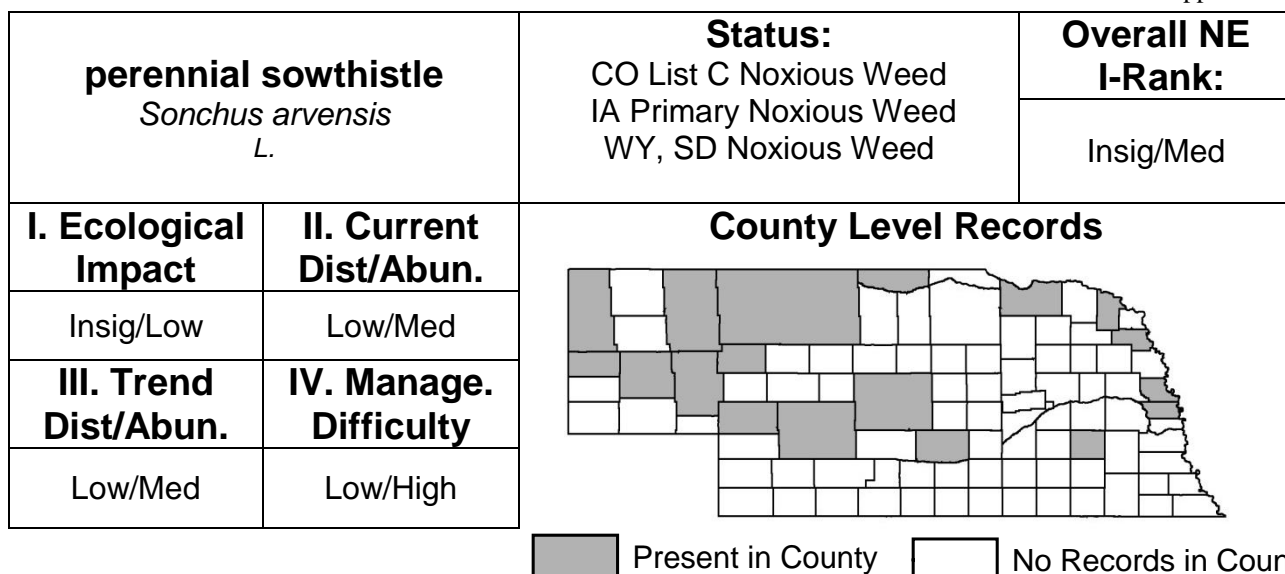


Comments:

This species is introduced from Eurasia and often escapes into fields, gardens and roadsides. It has a scattered distribution in Nebraska, but occurrences usually do not persist (Kaul et al. 2006).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

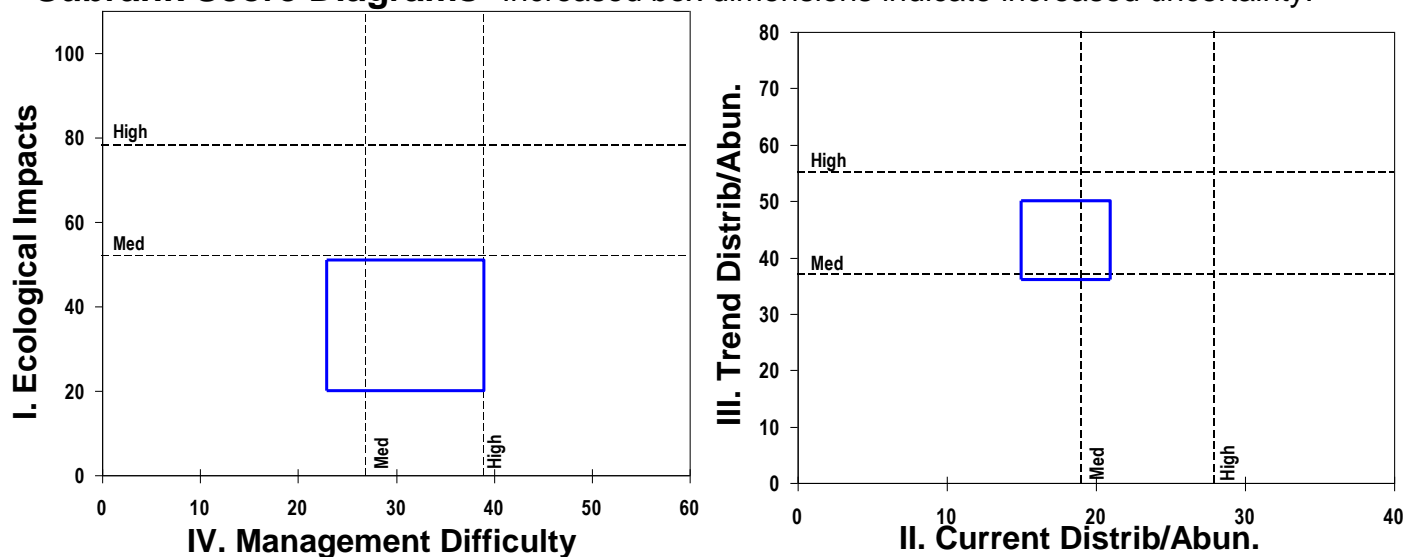


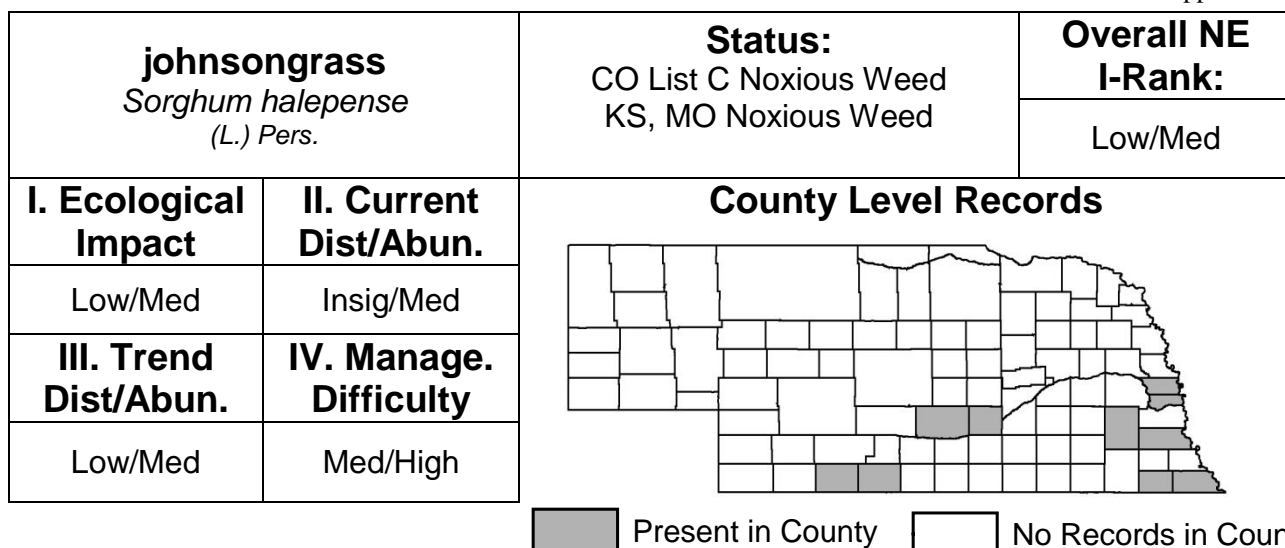


Comments:

This plant is native to Europe, and was documented in Nebraska by 1971. Observations indicate invasion of wet meadows of the Niobrara and North Platte Rivers. It seems to be spreading east from the Panhandle (Rolfmeier 2007). It is common in moist places in the panhandle and west Sandhills, being rarer in the central Platte Valley and eastern Sandhills, and absent from south and southeast counties (Kaul et al. 2006). Notable Survey Comments: Rapidly expanding in Panhandle wetlands; fairly common in somewhat disturbed moist habitats; some plants present- no dense populations. Grows in disturbed areas. Scattered infestations, but not increased severity (PRIDE).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

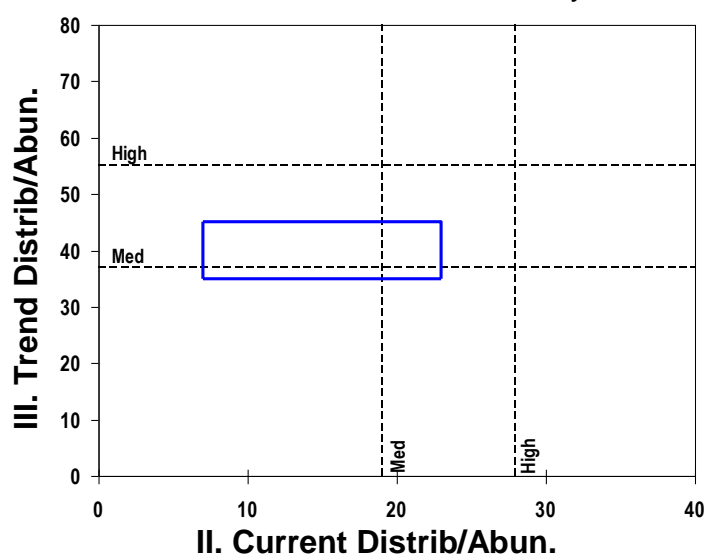
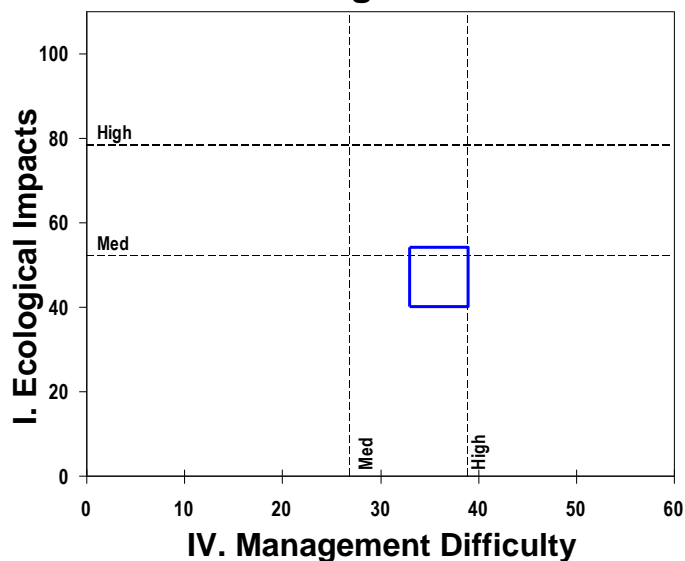


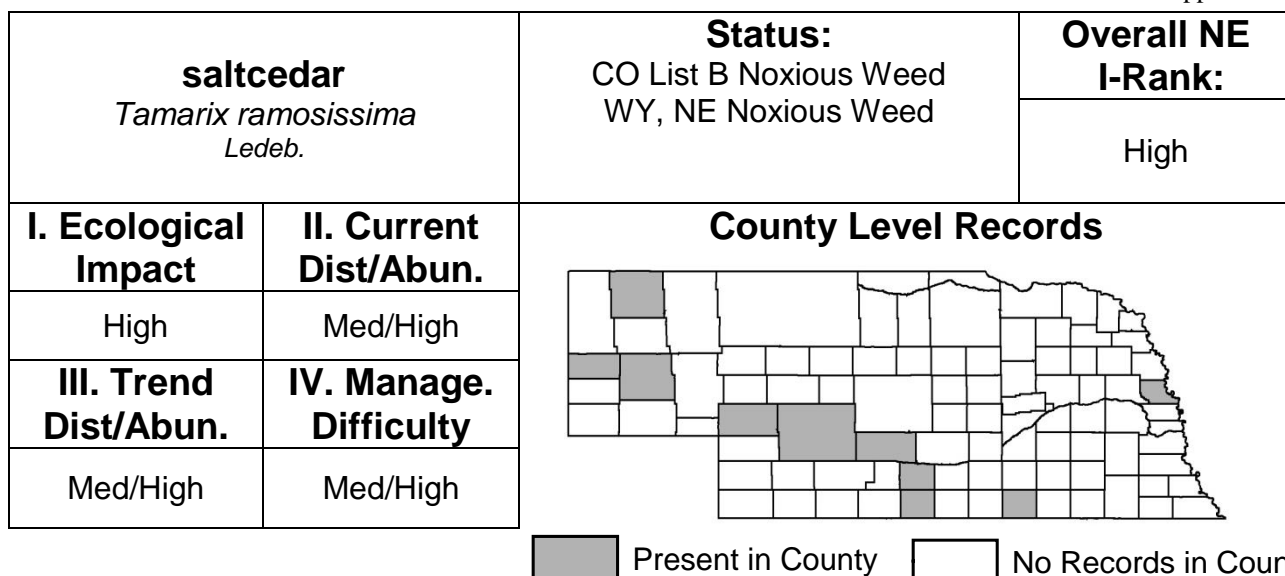


Comments:

This grass species is introduced from Europe and occurs in Nebraska in moist areas (roadsides, ditches, and field margins), mainly in southeast and south central Nebraska (Kaul et al. 2006). Within the Great Plains it occurs mostly in the southern portions, where it spreads rapidly and is difficult to control (Stubbendieck et al. 2003). Notable Survey Comments: still not a serious problem here mostly a roadside nuisance plant; better treatment reducing impacts (Platte Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

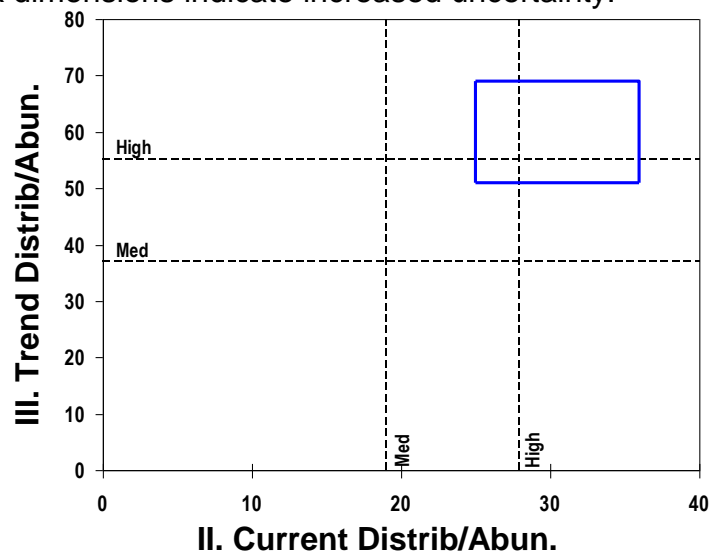
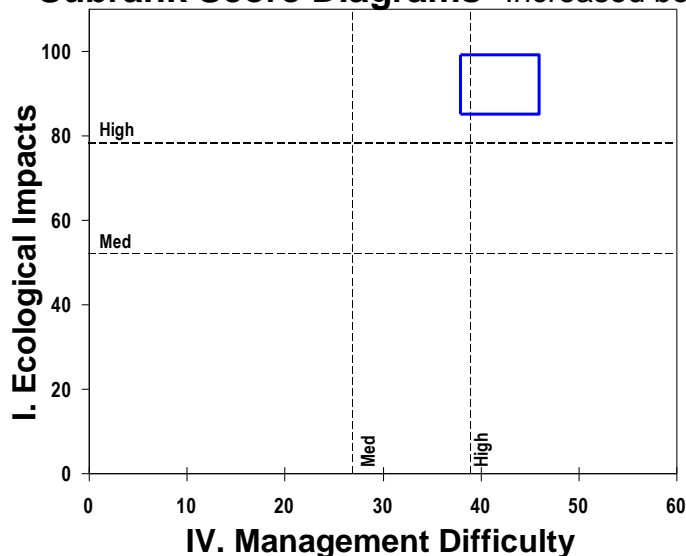


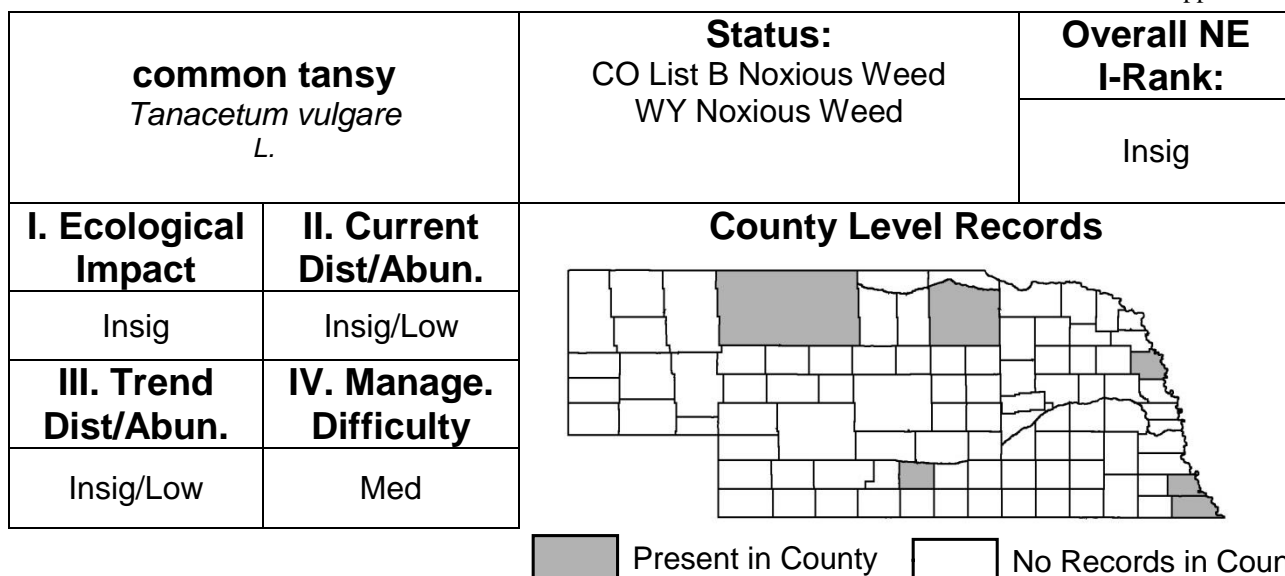


Comments:

Saltcedar is native to Eurasia, and was documented in the North Platte Valley in the 1970s. It occurs mostly in the western portions of the Great Plains, typically in salt marshes, flood plains, lake shores, and along rivers and streams (Stubbendieck et al. 2003). In Nebraska it is often observed on sands and gravels in the central and west Platte Valley (Kaul et al. 2006). Notable Survey Comments: has been long established (at least since early 70s) and unusually slow spreading. I'm more worried about it being a problem in the Panhandle, though not a huge problem there yet; serious invader of river bottoms. Have seen it at lake McConaughy. Is present in ravine adj. to Cedar Canyon WMA (Scotts Bluff Co) and in Arikaree River in SW Dundy Co. Appears to be expanding rapidly; we sprayed approx. 20 plants in 2007 (Northeast Neb); keeps showing up across the area! (West Central); expansion related to new discovery as riparian zones are inspected- treatments are reducing known infestations (Platte Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

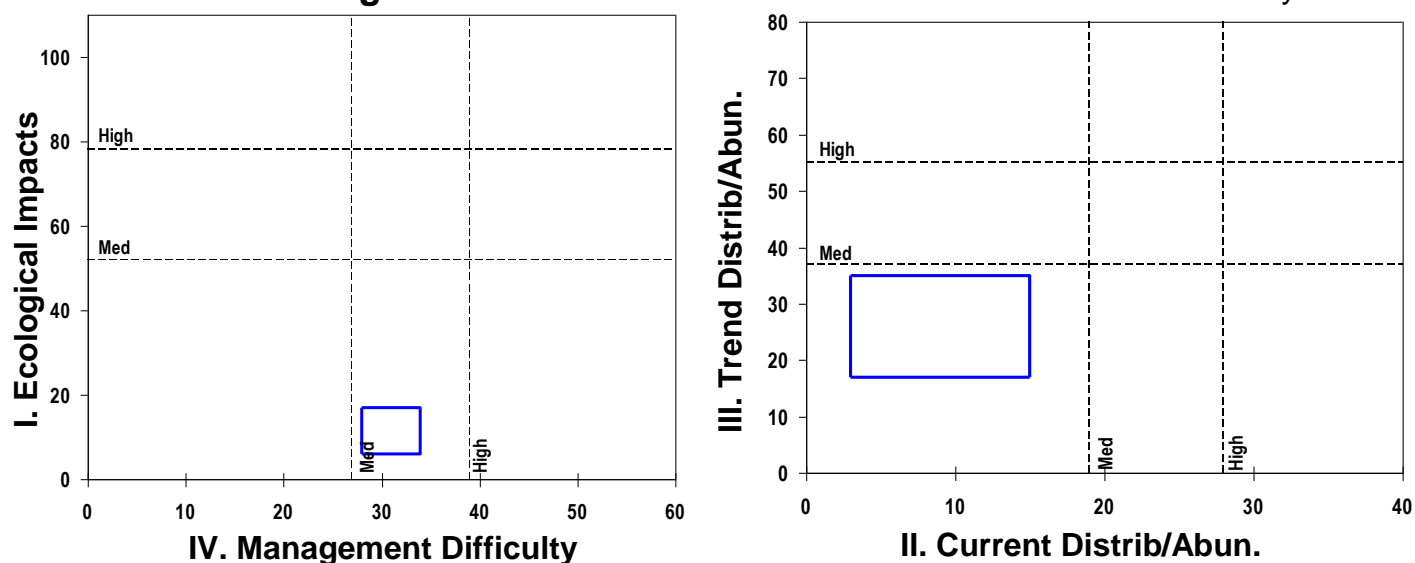


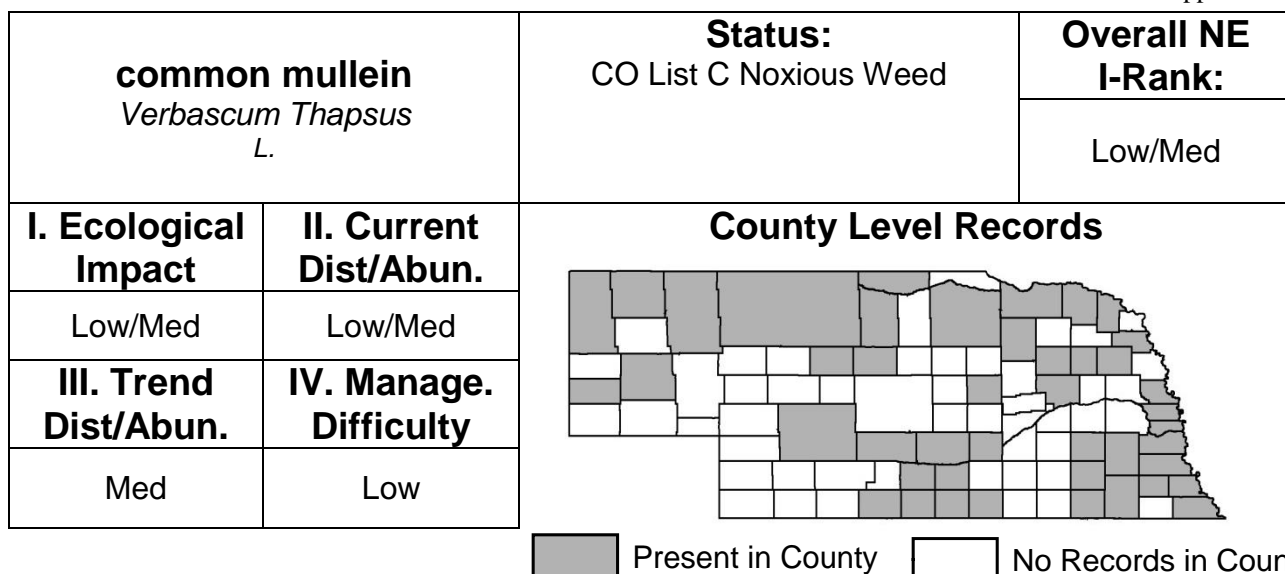


Comments:

This European plant occurs along moist roadsides, waste places, and gardens, being most abundant in northern and eastern Nebraska (Kaul et al. 2006). Notable Survey Comments: A casual alien; a rare plant in Nebraska, not a potential problem here; fairly uncommon and confined to highly disturbed habitats.

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.





Comments:

From Europe, this plant occurs in places like pastures and roadsides. It varies from sparsely scattered to locally abundant throughout Nebraska, and was first documented in the state in 1885 in Nemaha County (Kaul et al. 2006). It occurs throughout the Great Plains, being most abundant on coarse soils (Stubbendieck et al. 2003). Notable Survey Comments: pretty much ubiquitous and fluctuating in response to year-to-year conditions; Weed of highly disturbed areas little to no effect on biodiversity; If left uncontrolled, becomes very aggressive. Levels of infestation increase rapidly. Takes advantage of drought, overgrazed, disturbed areas (PRIDE). May have increased due to previous years of drought (Platte Valley).

Subrank Score Diagrams- Increased box dimensions indicate increased uncertainty.

